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ORIGINAL ARTICLE

Tibial pilon fractures treated with hybrid external fixator: analysis of 75 cases

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Abstract

Introduction The treatment of tibial pilon fractures is a surgical challenge due to the particular anatomical and vascular characteristics of this area, and the severity of the injury that can compromise soft tissues. Nowadays there is no gold-standard treatment for these fractures.

Materials and methods We reviewed 75 patients with tibial pilon fracture type C (AO classification) treated with hybrid external fixation (Stryker TenXor®). The surgical technique was reported. We evaluated clinical (Tornetta's score, VAS score, range of motion) and radiographic outcomes.

Results In 71 cases, the first surgical treatment was definitive. Instead, in four cases, it was necessary a second surgical procedure to achieve fracture healing. We obtained 44% excellent, 40% good, 7% discrete, and 9% bad results. We found a 30% of superficial infections of the pin site, resolved with oral antibiotic treatment (amoxicillin and clavulanic acid). We never had deep infections, no neurovascular injury, and no cases of secondary amputation. Although not statistically significant, we noticed a correlation between longer recovery times and trauma severity, with slower recovery in open or grade III fractures or when associated with other fractures.

Conclusions According to the recent literature, we think that the best treatment for non-articular fracture is the internal osteosynthesis within 6 h or after 6 days from trauma. In articular fractures, the elective treatment is the two-step management. In complicated articular fractures (Tscherne > 2, open, comminuted type III) is highly indicated the external fixation combined with minimal internal synthesis.

Keywords Tibial pilon · Distal tibia · Fracture · Osteosynthesis · External fixator · Hydrid · Tenxor

Introduction

Distal tibial fractures, also known as "tibial pilon fractures," are divided in "low-energy" fractures, due to rotational trauma (e.g., ski accidents), or "high-energy" fractures as in case of motor vehicle accident, high-height fall, or industrial accident [1, 2].

In high-energy tibial pilon fractures, the anatomical and vascular characteristics of the affected area and the severity of injuries determine a difficult choice of the management of these fractures [1, 2]. Despite the progress of surgical procedures, outcomes are not always excellent and complications unfortunately affect many patients. There is no gold-standard treatment [3]. In recent years, the use of external fixator came back and today is an absolute indication for open fractures, comminuted type C fractures, and in case of soft tissue involvement. The external fixation reduces the incidence of postoperative short-term and mid-term complications, producing clinical results in line with other methods [4].

Materials and methods

We reviewed 75 consecutive patients with tibial pilon fracture type C (AO classification) treated with external fixation (Stryker TenXor®), from January 2001 to February 2010.

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We used the Ruedi and Allgower fracture classification for its simplicity, reproducibility and close correlation with prognosis [5, 6].

Each patient received a clinical and radiographic evaluation using the Tornetta score [7].

Furthermore, we evaluated VAS score, range of motion, and varus–valgus angle of the joint plane to have a comprehensive assessment of the outcome, both functional and radiographic.

According to Italian law, the ethical approval for this study was not required because it involved only a clinical routine follow-up and a radiographic examination. We obtained a written informed consent directly from the patient. With this approval, the patient authorizes the surgical treatment and also the collection and publication of clinical data about his case for scientific and educational purposes even outside the institution.

Surgical technique

The surgical treatment of the fracture was typically performed within 24–36 h from injury. This permits a best management of soft tissues, protecting them from second traumatic hit (Fig. 1). The goals of the treatment are to restore tibial axis, permit bone healing, and spare soft tissue.

The patient was in the supine position. The trans-skeletal traction, if present, was removed. The first phase of the surgical technique was the stabilization of the fibula in order to restore the length and provide a lateral support which prevents the varus–valgus displacements of the fracture. Generally, we made a minimal synthesis of the fibula with percutaneous distal–proximal K-wires, one or two, from the apex of the malleolus. The second phase was the reduction in the tibial articular surface. Firstly, realign the central fragment with the posterolateral part of the articular block. Then reduce the anterolateral fragment to the posterocentral block. Finally, reduce the medial fragment, with attached malleolus, to the lateral articular block. The preliminary reduction can be stabilized with small K-wires, inserted percutaneously. In most cases, the simple closed reduction was satisfying, and in the presence of severe comminution and collapse of metaphyseal bone, we used a curved impactor introduced with a short skin incision into the fracture or through a cortical window in the metaphysis to reduce the articular fragments. Once restored the articular surface, we performed a minimal osteosynthesis of the tibial fracture with cannulated screws (5 mm diameter). The screws were positioned parallel to the joint surface in order to stabilize the Tillaux and the posterior fragment (Fig. 2). Then, we performed the external fixator positioning. We used for all patients the Hoffmann II (Stryker®) external fixator in its hybrid version Tenxor. The K-wires of hybrid external fixator create a support in the subchondral bone for the articular surface. The positioning of the K-wires, usually three wires, was described in the Bianchi-Maiocchi atlas [8].

The Kirschner wires were positioned about 1 cm above the articular surface, proximally to the screws. The first wire was introduced at the level of the fibula with the postero-anterior and lateral–medial direction and with an inclination of about 45°; the second one was introduced into the anterolateral part of the distal tibia with the postero-medial direction and an inclination of about 60° than the previous; the third wire was introduced anteriorly the fibula in the latero-medial direction, corresponding to the bisector of the angle formed by the first two wires. At this phase, each wire was fixed in special connection terminals to the carbon ring. Each wire was clamped and tensioned up to 100 kg. The ring was positioned in parallel to the joint plane. In

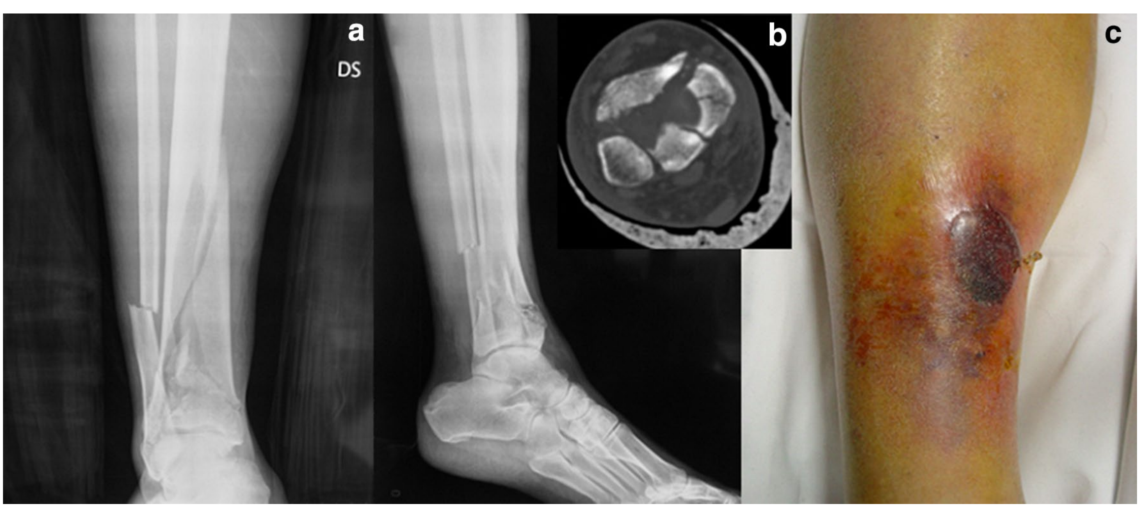

Fig. 1 Tibial pilon fracture type III. **a** Xrays. **b** CT scan. **c** Clinical state

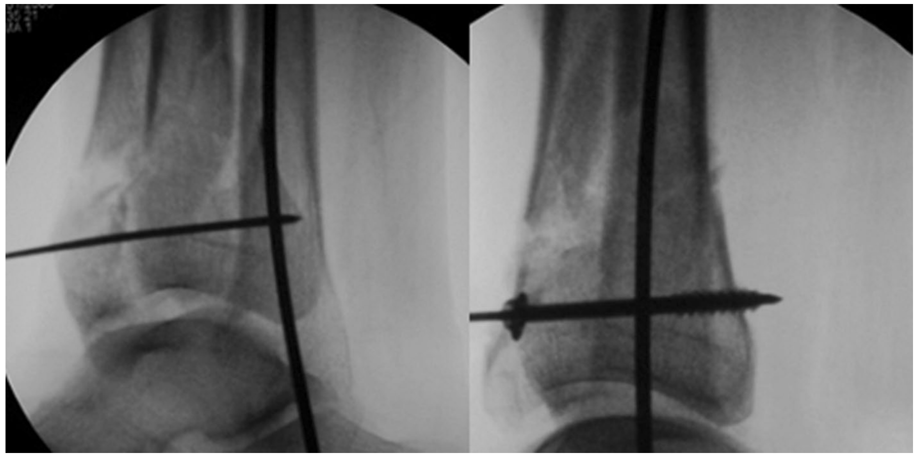

Fig. 2 Minimal osteosynthesis of the articular surface

the presence of considerable fracture displacement, each of the three wires may be with an olive to reduce and stabilize fracture fragments (Fig. 3).

Then we proceeded with the positioning of 3 pins (diameter 5 mm and length 120 mm), through the anterior ridge of the tibial diaphysis, proximal to the fracture. These were placed manually under X-ray control, through small skin incisions and using soft tissue protector, making sure to obtain a bi-cortical purchase. Finally, after a satisfactory fracture alignment, we connected and tightened the pins to the ring with carbon rods. The external fixator frame may vary depending on the fracture pattern; generally, we performed a triangular symmetrical configuration (Fig. 4).

In the presence of displaced "butterfly" fragments, we stabilized them with additional wires with olive to improve implant stability (Figs. 5, 6).

At the end of the assembly, if the X-ray control shows a system instability or an ankle ligament laxity, we could complete with ankle bridge, that had maintained for 30 days.

The postoperative immediate equinus attitude of the foot was managed by placing a sling that was held to the external fixator.

On the first postoperative day, patients began passive and active assisted ROM exercises on the ankle and knee joint. The discharge occurred 2–3 days after surgery.

All patients were followed up clinically at least every 15 days in a dedicated outpatient ambulatory care clinic, and moreover, they had a radiographic control every month to evaluate the need for system axial adjustments and the progression of fracture healing, and to schedule the removal of the fixator at the appropriate time.

On average 40 days after surgery, patients began a partial weight bearing with 15–30 kg weight limit, reaching 50 kg after 70 days, until full weight bearing after 90 days. The fracture pattern can bring forward or postpone the weight bearing beginning.

The removal of external fixator was always done in day surgery under mild sedation.

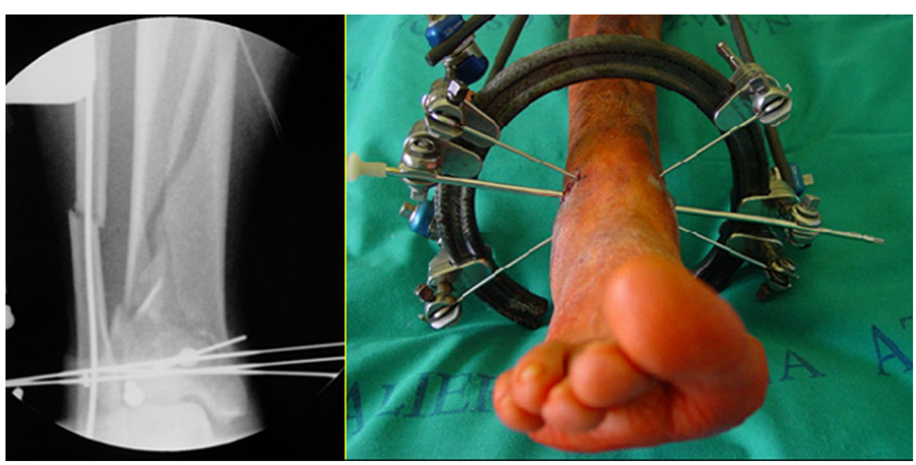

Fig. 3 K-wires positioning

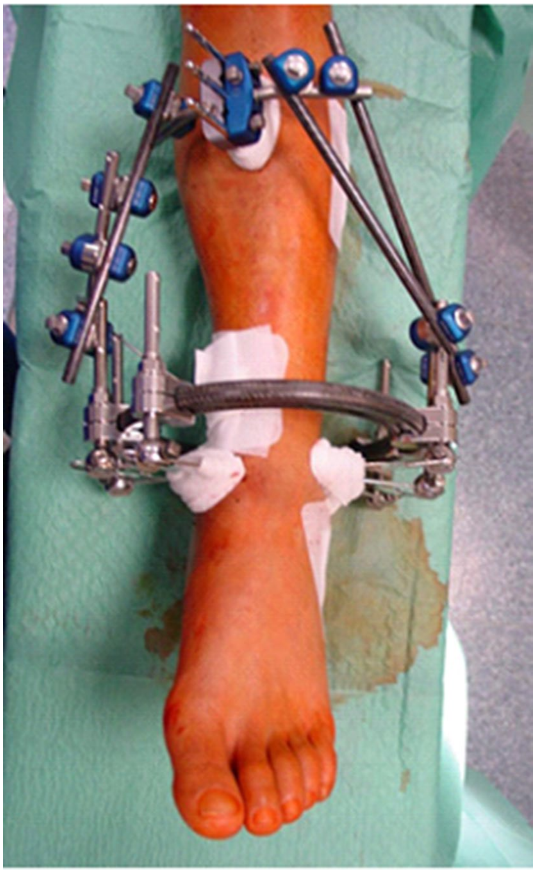

Fig. 4 Tibial hybrid external fixator frame

Results

We reviewed 75 patients, 50 men (66.7%) and 25 women (33.3%), with a mean follow-up of 39 months (range 36–86 months). The average age was 49 years old (range 16–80 years).

There were no significant laterality differences; we had one case of bilateral fracture (only one side treated with external fixator). Eleven fractures were open (14.6%). In 60 cases (80%), there were other associated fractures (such as distal radius, calcaneus, contralateral lower limb, humerus), and only 2 of them were polytrauma.

Evaluating the trauma mechanism, a high-energy trauma was the most frequent cause of injury (54 cases, 72%). 72% of them were caused by motor vehicle accidents, 22% were caused by high-height fall, including one suicide attempt, 6% from crush injuries (work accidents). The remaining 21 cases (28%) were the result of low-energy trauma.

In 71 cases, the first surgery was the definitive treatment. Instead, in four cases, it was necessary a second surgical procedure to achieve fracture healing: in two cases, we added cancellous screws to optimize the fixation stability without external fixation change; in other two cases, we converted the external fixation to ORIF. The external fixator was removed after a mean time of about 4 months (from 3 to 5 months) from surgery.

Using the Ruedi–Allgower's classification, we found 27 extra-articular (36%) and 48 articular fractures (64%), including 20 type II fractures and 28 type III fractures.

Based on the Tornetta criteria [7], the results obtained were:

- 44% excellent (33 cases);

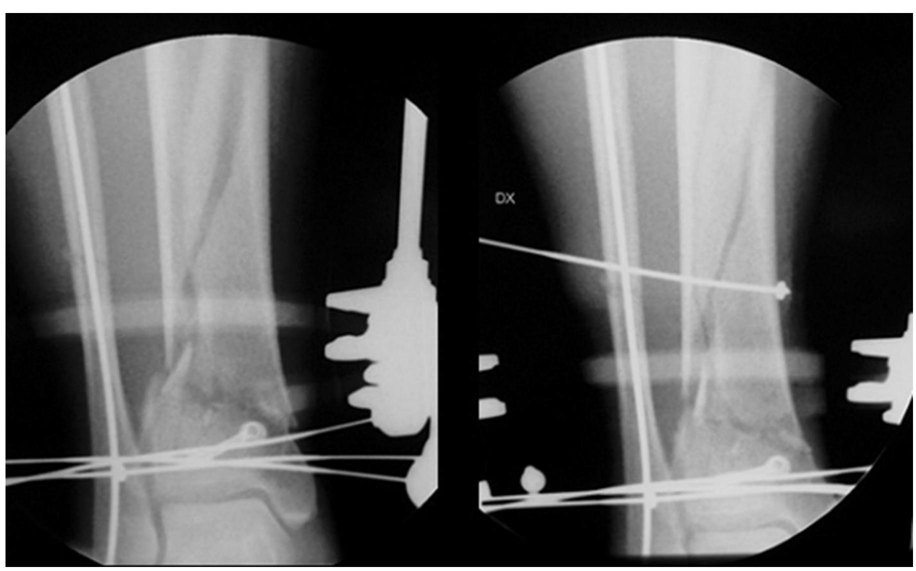

Fig. 5 Fracture reduction and stabilization with additional wire with olive

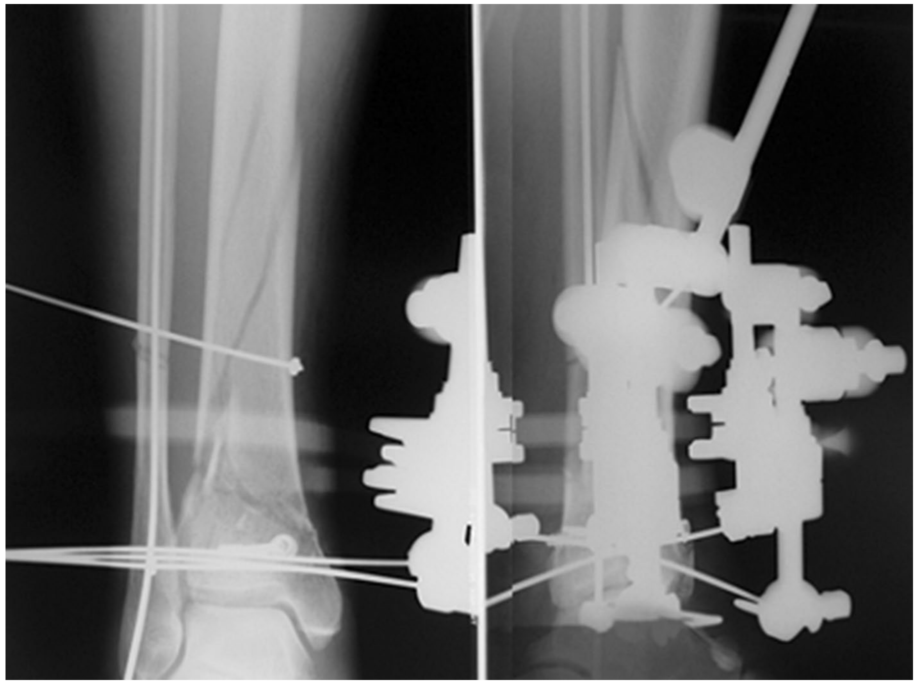

Fig. 6 Post-operative xrays

- 40% good (30 cases);
- 7% discrete (5 cases);
- 9% bad (7 cases).

We reported a 30.6% of superficial infections of the pin site, resolved with oral antibiotic therapy (amoxicillin and clavulanic acid). In one case, a prolonged direct sunlight exposure caused a colliquative necrosis of the skin and a tissue infection adjacent to the K-wires: In this case, the external fixator was removed and replaced with a leg cast for a month without weight bearing. We never had deep infections, no cases of neurovascular injury and secondary amputation.

Only one patient changed his pre-injury job and habits, despite a good radiographic result.

Although not statistically significant, we observed a correlation between longer recovery times and trauma severity, with slower recovery in open or grade III fractures or when associated with other fractures (calcaneus, contralateral lower limb or shoulder).

Discussion

The management of high-energy tibial pilon fractures is still complex for the high incidence of short- and medium-term local complications (infection, delayed healing, non-union or vicious consolidations) and long-term complications, such as post-traumatic osteoarthrosis. The traumatic mechanism involves also the soft tissue, which, for the poor vascularity and bone proximity, becomes suffering. For these reasons, the choice of treatment should be accurate [9]. Evaluating the outcomes of this type of fractures with subjective questionnaires, the results are worse than in pelvic ring fractures or AIDS patients, independently from the type of treatment [10]. Nearly half of patients have lost their jobs and two-thirds attributes this to the fracture outcomes [11].

The goals of treatment are to reduce the articular surface, restore the tibial axis, prevent the soft tissues injury, and facilitate the bone-union [6, 12, 13]. There are many different treatments: Open reduction internal fixation (ORIF) one-step, temporary external fixation + ORIF two steps, definitive external fixation with or without limited internal fixation. In low-energy and not complex fractures, it is recommended a temporary external fixation and a subsequent open osteosynthesis. In high-energy fractures, in the more recent literature, the use of definitive external fixator associated with a limited internal fixation is returning as the gold-standard treatment [14–17].

The use of a definitive treatment with external fixation reduces the early complications, especially deep infections [15]. For the high incidence of soft tissue complications in type III tibial pilon fractures, the ORIF one-step treatment is not acceptable. In our series, we did not have major complications, such as deep infection and amputation. Wyrsch et al. [18] compared the incidence of complications in the external fixation and ORIF technique. In ORIF group, there was an incidence of 28% of deep infections, 33% of wound dehiscence, and 16% of secondary amputation. In the group of patients treated with external fixation, there was only a 5% of infection and no cases of amputation.

A comparative study of 60 fractures performed by Pugh et al. [19] showed that the external fixation provides numerous advantages in the soft tissue management but tended to miss the initial reduction, better dominated with ORIF. However, in the cases treated with plate synthesis, there were two amputations.

Papadokostakis et al. [20] evaluated 465 fractures, 71% of which were type C, comparing two external fixation systems (monoaxial vs. hybrid). They concluded that there is no clear difference between the two techniques, achieving similar long-term results. Malunions are greater in monoaxial frame probably for the inability to maintain the initial reduction only by ligamentotaxis.

Biomechanical studies demonstrated how a multiplanar montage, with tensioned and crossed wires, creates an efficient "scaffold" of the distal tibia to protect the articular surface from the loss of reduction and allows an early weight bearing, with excellent stability similar to the double plate.

In our experience, the external fixator montage provided a good stability, only failing when the fracture was very close to the articular surface with comminution of the medial face and collapse of cancellous bone.

From this review, we achieved a successful result (excellent and good) in 84% of cases. Then, comparing our results with the literature, we observed that they are comparable with others studies where external fixation is the elective surgical method, as in the Tornetta's study that showed 81% of positive results [7]. As reported in the literature, the worse results are related to the high degree of fracture comminution. We noticed a clear correlation between the outcome and the complexity of the fracture, and the best results were obtained in non-articular and type I/II fractures. While the worst results were obtained in type III, articular, and comminuted fractures: Greater is the number of fragments, greater will be the incidence of bone necrosis and post-traumatic osteoarthritis. By comparing the two techniques, external fixation and internal fixation, the external fixation has clinical results comparable to ORIF technique, without substantial differences. The ORIF has improved the joint reconstruction with a better radiographic outcome, while the external fixation gives a reduction in bleeding and hospitalization [21, 22].

In long-term follow-up patients, about 8 years, we reported a deterioration of ankle joint toward post-traumatic arthrosis, to which all patients seem to be destined. The radiographic results did not match the clinical ones, and in most part of cases, our patients performed normal daily activities and their work. There was a significant correlation between the fracture site and the interval of the development of osteoarthrosis; in fact, the latency time was significantly greater for extra-articular fractures (40.4 years) and lower in articular fractures (19.3 years). The same correlation existed between latency and severity of the fracture: Greater severity is associated with lower latency time. The average age of patients with ankle post-traumatic osteoarthrosis was 55.7 years, and older patients developed a faster osteoarthrosis [23].

Crutchfield [24] described the severity of the fracture as a prognostic factor. In a study of 38 fractures, independently of the treatment, the simplest fractures showed generally better results.

Chen et al. [25] in a study including 128 tibial pilon fractures with a mean follow-up of 10 years (39 patients with type I fractures according Ruedi's classification, 62 type II and 27 type III) showed that open reduction and plate fixation are great for type I fractures and that the long-term results are influenced by the type of fracture, the restoring of the fibula length, the quality of the reduction, and severity of the soft tissues damage. The post-traumatic osteoarthrosis occurred primarily in type II and III fractures.

The type of fracture, as well as the quality of the reduction, correlates with post-traumatic osteoarthrosis and clinical outcomes [26]. In literature, the rate of ankle arthrodesis after post-traumatic osteoarthrosis in Type I or Type II Ruedi fractures is 10% while in type III fractures reaches 26% [27].

Conclusions

In most part of complex fractures, the open technique can lead to complications that could be avoided with external fixation. Our treatment with the definitive external fixator ensures long-term clinical results similar to other open techniques, reducing at the same time short- and medium-term complications. In addition, when the radiographic result is not satisfactory, it does not affect the use of subsequent invasive surgical techniques. In our experience, the hybrid external fixator is a simple technique, safe, and really minimally invasive.

Its disadvantages are as follows: the X-ray exposure, a minor anatomical reduction, and the need of a structure for the continuative postoperative management, with knowledgeable and experienced équipe, who knows the fixator, the nursery and how to recognize and treat superficial infections, loss of reduction or stability.

According to the recent literature, we think that the best treatment for non-articular fracture is the internal osteosynthesis within 6 h or after 6 days from trauma. In articular fractures, the elective treatment is the two-step management. In complicated articular fractures (Tscherne > 2, open, comminuted type III) is highly indicated the external fixation combined with minimal internal synthesis.

Compliance with ethical standards

Ethical approval According to Italian law, the ethical approval for this study was not required because it involved only a clinical routine follow-up and a radiographic examination.

Informed consent We obtained a written informed consent directly from the patient. With this approval, the patient authorizes the surgical treatment and also the collection and publication of clinical data about his case for scientific and educational purposes even outside the institution.

Conflict of interest All authors declare that they have no conflict of interest.

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