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Major trauma, definitive treatment of the lower limbs

Antonio Medici[1], Emilio D'Onofrio[2], Manuel Giovanni Mazzoleni[2], Biagio Tangredi[2], Antonio Tramontano[1], Alfonso Maria De Simone[1]

[1] A.O.R.N. "G. Moscati" hospital, Avellino, Italy; [2] Medical school, Orthopaedic Surgery Post Grade, University of L'Aquila, L'Aquila, Italy

Summary

Multifocal fractures of the femur in modern traumatology are becoming more frequent and often pose difficult problems for treatment. These fractures are frequently associated with other comorbidities, necessitating thorough trauma life support assessment and interdisciplinary care. Associated ipsilateral femoral neck fractures have been reported to occur in 1% to 9% of femoral shaft fractures. The associated femoral neck fracture is often nondisplaced, and diagnosis is delayed or missed in up to one-third of cases. It is essential to carefully evaluate the femoral neck in all patients sustaining high-energy femoral shaft fractures. No consensus exists regarding the timing of surgery, sequence of fixation, or the optimal implant choice in the treatment of ipsilateral femoral neck and shaft fractures because these fractures are relatively rare, and patients often present with concomitant multi-system injuries. Fixation of these combined injury patterns is challenging, and multiple treatment options exist. Treatment goals should include anatomic reduction and adequate fixation of the femoral neck fracture, as well as restoration of the length, alignment, and rotation of the femoral shaft fracture. While most authors recommend surgical fixation within 24 hours, if possible, and to give priority to anatomic reduction and optimal stabilization of the femoral neck fracture because nonunion, malunion, or avascular necrosis of this injury is more difficult to successfully treat, other studies demonstrate that the use of separate implants can lead to a better result.

Key words: femur, multifocal fracture, shaft fracture, fracture dislocations

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Correspondence
Emilio D'Onofrio
Medical school, Orthopaedic Surgery Post Grade, University of L'Aquila, via Lungosabato don Emilio Matarazzo 8, 82100 Benevento, Italy
E-mail: emiliodonofrio87@gmail.com

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The case report

A 40-year-old male presented to the Emergency Department following car accident polytrauma. The initial management was performed according to ATLS guidelines and included Focused Assessment with Sonography in Trauma (FAST), chest x-ray and pelvic anteroposterior (AP) X-rays, CT-trauma scan, and femoral x-rays. He presented with swelling and deformity of the right thigh, accompanied by limited mobility of hip and knee. The patient was hemodynamically stable and there were no neurological ad vascular symptoms.

X-rays showed up a multifocal fracture that we classified as AO31-A2 and AO32-C2 (Fig. 1). We planned the reduction of the shaft first and then the neck with an early definitive treatment in the first 24 hours from admission. We decided to implant an antegrade cephalomedullary nail, on a standard traction table, since we could reduce the shaft first and then the neck in a single step using a single device table. (Fig. 2). The patient never started assisted the weight-bearing prescribed. After 8 months, X-rays showed an atrophic nonunion fracture site with a double deformity, and the 3rd posterior fragment did not mobilize after nonunion (Fig. 3). Because

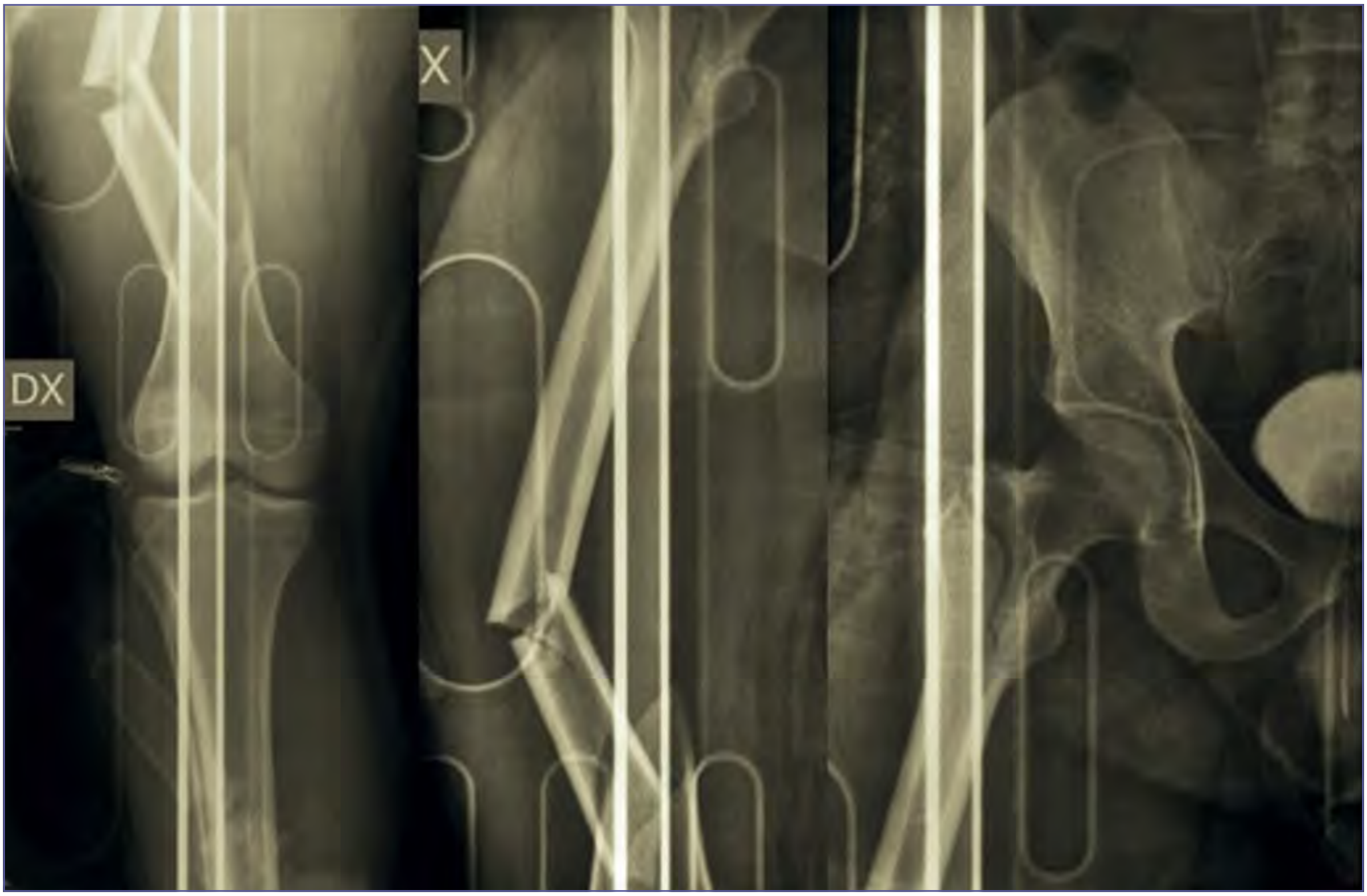

Figure 1. Trauma x-ray (AO31-A2/AO32-C2).

of neck healing, we planned to change the device, deciding to remove the anterograde nail and, after reaming the canal, to implant a retrograde nail (Fig. 4). After 6 months, bone defect and malunion were not resolved and there were no signs of healing, and we again decided to change the type of implant and use a more aggressive approach. We planned to implant a femur plate and screws, after removing a necrotic fragment and filling the bone defect with an anterior and medial cortical iliac graft (Fig. 5). Following this, the patient started his rehabilitation program and finally returned to normal life activity.

Introduction

Femoral shaft fractures can result from high or low energy mechanisms and are often associated with other serious injuries. The most common causes include automobile accidents, falls from heights, ground-level falls in individuals with osteoporosis, and gunshots [1].
The worldwide incidence of femoral shaft fractures ranges between 10 and 21 per 100,000 per year [2].

Ipsilateral femoral neck fractures occur in 2% to 9% of all femoral shaft fractures. The average age of patients is 35 years, and 75% of patients are male. The shaft fracture is typically comminuted, in the middle on third of the diaphysis, and is open in 15 to 33% of cases [3]. The neck fracture is usually basicervical, vertically oriented, and is nondisplaced in 60% of cases. Between 75 and 100% of patients have multisystem injuries, and 20 to 40% of patients have ipsilateral knee injuries, including ligamentous injury, tibial plateau fracture, patellar fracture, or knee dislocation [3,4].

Materials and methods

We performed a narrative review of the available English literature in order to evaluate the management of multifocal fracture of femur.
The PubMed, Embase, Medline, Medscape, Google Scholar and Cochrane library databases were screened for relevant studies.

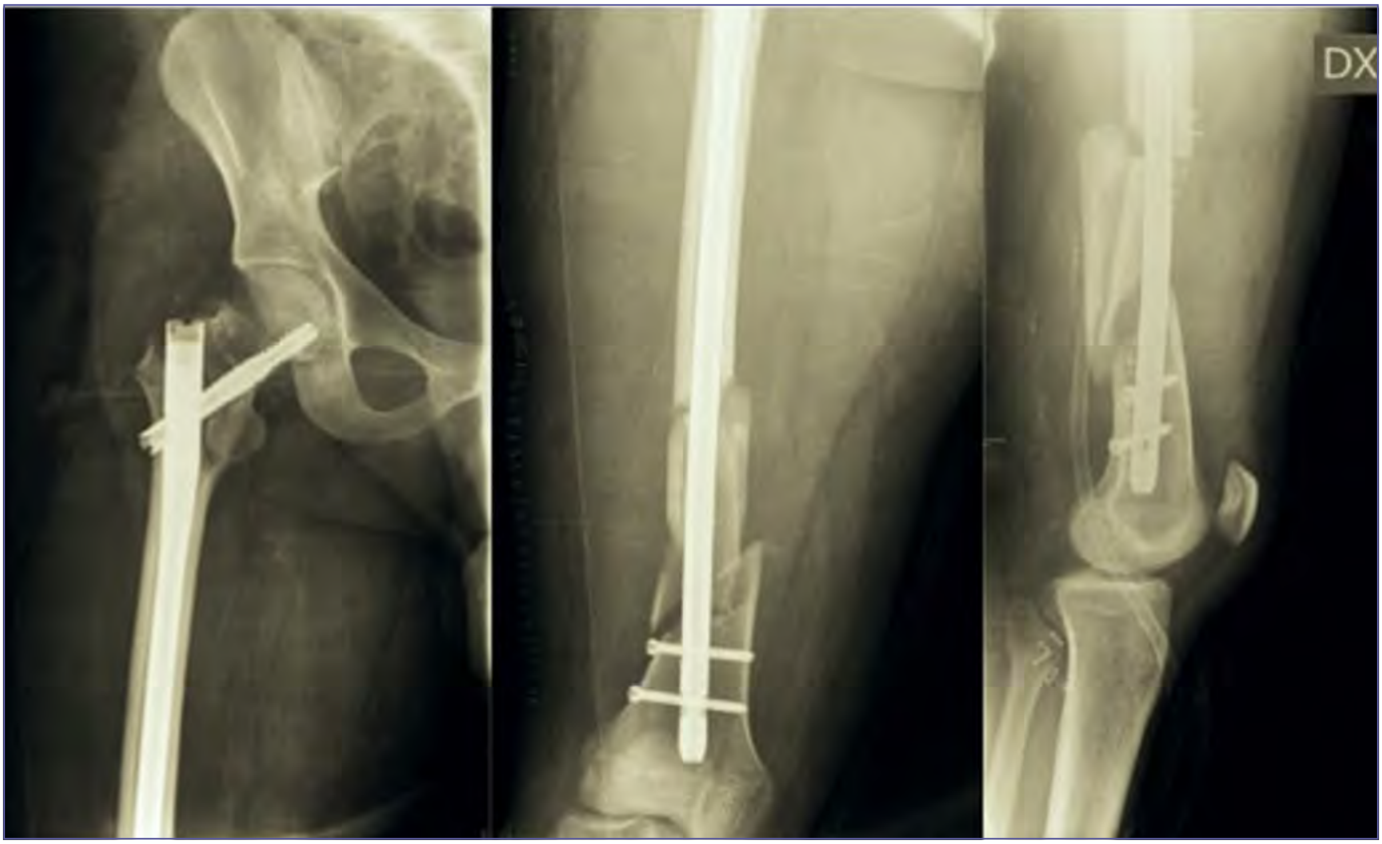

Figure 2. 1st step, antegrade cephalomedullary nail.

Figure 3. Eight months follow-up: malunion.

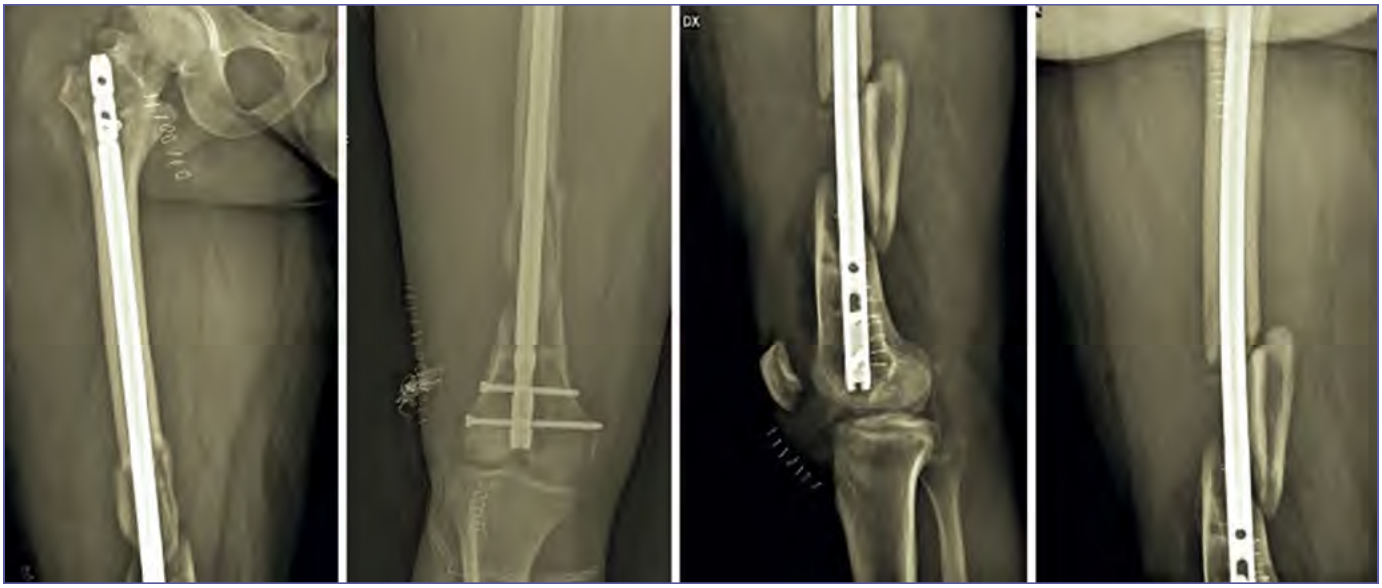

Figure 4. 2nd step, retrograde nail.

Figure 5. 3rd step, femur plate and screws with cortical iliac graft.

Results

Mechanism of injury (MOI)

In 1958 the concept of the so-called dashboard femoral fracture was described. In high-speed motor vehicle collisions, the patient's knee strikes the dashboard, creating an axial force along the femur leading to a comminuted diaphyseal femur fracture. Posterior hip dislocation may occur in case of adducted hip, but, in case of abduction of the hip, femoral neck or acetabular fracture can ensue [5].

In 1981, Zettas et al. [6] were the first to hypothesize that even in high-energy trauma with comminuted femoral shaft fractures, the associated femoral neck fracture was frequently nondisplaced. They postulated that most of the energy was "initially and partially released by the fracture of the femoral shaft, followed by the femoral neck fracture". Since then, several au-

thors have hypothesized that most of the energy in this injury pattern is absorbed by the knee and diaphyseal femur fracture, leading to a nondisplaced, easily undiagnosed femoral neck fracture.
Regardless of the mechanism, the deforming forces of a fracture depend on the fracture characteristics. Associated orthopedic injuries of the femur that must be ruled out include fractures of the proximal femur (femoral head and neck, intertrochanteric fractures), and bilateral femoral fractures. The presence of associated injuries is clinically relevant because it will affect the timing, decision making, order of fixation, and implant selection [7].

Diagnosis

This is of paramount importance of an ipsilateral femoral neck fracture in the setting of a femoral shaft fracture to prevent the potentially devastating complications of displacement, nonunion, and osteo-necrosis. Several authors demonstrated that up to 30% of femoral neck fractures associated with femoral shaft fractures were missed on initial assessment [8]. Anamnesis is the first step; MOI can help us to drive diagnosis. As most of these patients present with multisystem injury, the initial evaluation should follow the Advanced Trauma Life Support protocol to evaluate for life-threatening injuries. Usually, X-ray is the first imaging exam in polytraumatized patients, especially who are hemodynamically unstable. On the other hand, patients who are low life risk can be studied using computed tomography (CT). Use of CT was discussed for a long time because of some studies [4,9] that reported a missed diagnosis of femoral neck fracture in association with ipsilateral shaft fracture even if they were studied with CT.
It is good practice to obtain orthogonal radiographs of the suspected injured extremity, including the ipsilateral joints proximal and distal to the injury to characterize the fracture. These images help identify potential fractures to the acetabulum, proximal femur, proximal tibia, and patella and help identify a possible floating knee injury.
Tornetta et al. [4] proposed a protocol which includes ATLS, and then X-ray study in AP, LL, and Judet-like view of the limb including the proximal and distal joints and tibia, fine-cut CT scan, intra-operatively fluoroscopy views and a postoperative RX in orthogonal positions.

Treatment

There are several options of treatment including single constructs (e.g., cephalomedullary nail, long sliding hip screw, external fixation) and dual constructs (e.g., retrograde nail with sliding hip screw, proximal femoral locking plate, or cannulated screws).
No consensus exists regarding the timing of surgery, sequence of fixation, or optimal implant choice in the treatment of ipsilateral femoral neck and shaft fractures because these fractures are relatively rare, and patients often present with concomitant multi-system injuries.
Most authors recommend surgical fixation within 24 to 48 hours to reduce the incidence of pulmonary complications, infection rates, and mortality [10]. Delayed treatment, over 24-48 hours, increases pulmonary complications in up to 56% of patients compared to only 16% of patients treated early [11].
Debate also exists regarding the sequence of fixation of the two fractures. Some authors argue that the femoral neck should be fixed first to avoid displacement of a nondisplaced or minimally displaced fracture and to ensure anatomic reduction and optimal stabilization of the neck to prevent osteonecrosis and nonunion. Other authors argue for fixation of the shaft fracture first, stating that this will aid in the reduction of the neck and avoid destabilizing neck fracture fixation during shaft fixation [12].

Antegrade nailing

In early treatment, antegrade nailing is the gold standard with good outcomes [13]. In relatively young patients (e.g., age 50 years with good-quality bone) who present with ipsilateral femoral neck and shaft fractures, intramedullary devices are typically locked proximally with two smaller (approximately 6.0 mm) screws. In elderly or osteoporotic patients, it is better use a cephalomedullary nailing with a single larger screw (10.5 mm). Both techniques aim to fix both fractures with a single implant and fixing the shaft fracture before the neck fracture gives the surgeon the possibility to reach the best reduction. Wiss et al. [14] reported that antegrade nailing combined with lag screw fixation of the neck did not produce uniformly favorable results, which they attributed to the higher rates of varus nonunion of the neck fracture.
When a neck fracture is identified intra-operatively after nail insertion, it is possible to synthetize the neck fracture without removing the nail. Removing a nail can cause fracture displacement, and so the miss-a-nail technique can help the surgeon to place cannulated screws adjacent to the nail. Anatomically the axis of the femoral neck lies anterior to the axis of the femoral shaft, is possible to place neck screws there, "missing the nail" [15]. At least one manufacturer produces a "miss-a-nail" jig, which guides the placement of screws either anterior or posterior to the nail [12].

Retrograde nailing

The authors recommend reduction and fixation of a femoral neck fracture prior to insertion of a retrograde femoral nail because of the high risk of displacement. The use of a bone hook (placed at the base of the femoral neck) and Schanz pins (placed in the femoral head) can help restore Shenton's line and obtain adequate reduction. A good cortical read is often difficult to obtain in comminuted fractures, and the rotational component of the fracture can be challenging to correct. To limit the im-

paction force during insertion of a retrograde intramedullary nail, Boulton and Pollak recommended over-reaming the intramedullary canal by 2.0 to 2.5 mm [10].
Studies have demonstrated comparable outcomes for antegrade and retrograde nailing. Union (100 *vs* 99%), malunion (11 *vs* 13%), and nonunion rates (6 *vs* 6%) are similar for retrograde and antegrade approaches. A common complaint of retrograde nailing is knee pain, while for anterograde nailing it is hip pain and stiffness [16].

Femoral neck screws and plate fixation of the shaft

These are not a first choice because of the surgical dissection required and the weaker mechanical properties. However, because one may wish to maintain weight-bearing restrictions due to the femoral neck fracture, the mechanical issue may not be as critical. Plate fixation may be ideally suited for a displaced fracture in which wide exposure is required for fracture debridement, or for a patient with an intra-articular distal femur fracture in whom a retrograde nail would be contraindicated [17].

External fixation

Is indicated for patients with open fractures, vascular injuries, polytrauma, stabilization for transfer, and those unstable for early definitive care. External fixators can be applied with minimal effect on the trauma patient's disease burden. Proximal pins can be placed into the femoral neck and head, while distal pins may be placed in the distal femur or proximal tibia. Definitive treatment using external fixators is correlated with a high rate of complications, such as loss of reduction, malunion, pin site infections, osteomyelitis, nonunion, and joint stiffness, and for this reason it is used as temporary treatment [18].

Complications

Intra-operative complications include neurovascular injury, iatrogenic fractures, compartment syndrome, thermal necrosis, and malalignment. Postoperative complications include fat emboli syndrome, pulmonary embolism, infection, osteomyelitis, malunion, nonunion, and hip and knee pain. Reaming can cause increased temperatures of up to 57°C resulting in thermal necrosis secondary to enzyme denaturation, potentially leading to delayed fracture healing [19], and it is good practice to use correct reaming technique to reduce the complication rate.
Malrotation is one of the most significant complications of long bone fractures, with an incidence of up to 25%. Malrotation up to 14° from neutral is tolerated.
Comminuted fractures can present a significant challenge in determining leg length that can manifest as pelvic tilt, leading to hip pain and back pain. In a study of comminuted femur fractures, six patients had a leg length discrepancy greater than 1.25 cm, with only 4 of these patients requiring revision surgery [20].
Nonunion is a failure of the fracture to heal or lack of signs of healing for six months. Work up should include evaluation for infection as a cause of nonunion. Surgical treatment may include revision fixation with or without bone graft, depending on the cause of nonunion [21].
Problems with union can occur following both femoral neck and shaft fixation. Neck nonunion occurs in up from 1.2 to 10% [22,23].
The higher rate of neck nonunion seems to be higher with single device treatment, which could be attributable to the increased technical difficulty in achieving adequate femoral neck reduction, which in turn may affect union [24].
Bedi et al. [25] reported that the use of a separate implant in comparison to only a cephalomedullary nail leads to higher accuracy of femoral neck reduction. A potential reason could be that a separate device strategy may allow prioritization of initial neck fixation prior to shaft fixation.
Non-accurate intra-operative fracture reduction is associated with avascular necrosis. Femoral head (AVN) that occurs in up to 22% of cases is associated with poor patient outcomes [26].
Mohan et al. [23] found in their meta-analysis that time to femoral neck and shaft union was less (18.1 and 20.5 weeks respectively) in the single than the separate device group (20.5 and 22.8 weeks). They compared time to nonunion in two groups of patients treated with single and separate devices, and found that time to union in both fractures in both groups appeared to be acceptable. Nonunion of the femoral shaft is typically treated with either exchange nailing or compression plating, with or without bone grafting. Watson and Moed [27] found that all shaft nonunions healed with revision surgery, but that 2 of 10 nonunions required more than one revision surgery to achieve union. Mohan et al. [23] found that the unplanned reoperation rate in patients who had 1 procedure *versus* those who had separate devices is higher (11.1 *vs* 6.25%), and is associated with increased costs of hospital bed days.

Discussion

Following an analysis of the literature, we analyzed our case and recognized some decisions that could have been made differently. First of all, the patient was a major trauma victim, and we used the ATLS protocol. Neck fracture was diagnosed with X-ray because of displacement, and we did not study the fracture using CT. As a gold standard, we planned and placed an antegrade nail using a single larger screw (10.5 mm) instead of two smaller screws in first 24 hours. The reason of using a technique that is recommended in elderly patients is that we did not have the availability of the device that is recommended for younger patients. In accordance with the literature, shaft fracture has a higher rate of non-healing when associated with neck fracture, and in our experience this could be the reason that we did not reach adequate reduction in rotation and axis; in addition, the patient did not follow the rehabilitation program. Revision surgery was performed at 8 months after first surgery, and our decision to implant a retrograde nail was due to the similar success rate compared with antegrade nailing and because of the small distance of fracture rime from the access point of the nail. Reaming the femur channel is not always compatible with bone tissue biology, and as we found in the literature, reaming may can produce high temperatures that can lead to thermal necrosis; we also could not reach good axis restoration. The combination of these factors could be the main reason of nonunion. The last revision was performed choosing an open approach. The decision was made to try to obtain good fracture stabilization, remove necrotized tissue, and fill the bone defect using autologous and non-autologous bone graft. Even if we did not obtain anatomical reduction, the final functional outcome was good.

Conclusions

Management of concomitant ipsilateral femoral neck and shaft fractures remains a discussed topic. If, on one hand, there is no evidence base and consensus, surgical planning needs to be "tailor made" to the patient's condition. Always expect a multifocal pattern and prepare an optimal sequence or method of fixation for the management of ipsilateral femoral neck and shaft fractures. The surgeon should choose a surgical plan that optimizes anatomic reduction and adequate stabilization of the neck fracture, as well as restoration of the length, alignment, and rotation of the femoral shaft fracture. The surgeon at the same time should consider the biology and the physiology of the bone and its healing. If the fracture evolves into a nonunion, one needs to be able to change the plan and find the adequate treatment considering the skills/experience/confidence and available resources. On the other hand, consensus exists regarding the type of patient and mechanism of injury, and early suspicion for this injury pattern, in patients presenting with multiple injuries following high-energy trauma, which may allow for earlier diagnosis and potentially improve outcomes. This may be of importance as it permits increased clinical suspicion in diagnosing this rare injury. Last but not least, a reduced rate of reoperation can be associated with lower costs for the healthcare system in addition to obvious patient benefits.

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Author contributions
All the authors contributed equally to the work.

Ethical consideration
No experimental procedures have been conducted. No study design protocol approved by the Institutional Review Board was necessary for this study, as a standard and approved technique was applied. Consequently, for all of them it is not possible to identify any individual patient, according with WMA Declaration of Helsinki. All patients signed an informed consent for the surgical procedure.

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Via A. Gherardesca • 56121 Ospedaletto • Pisa
Telephone +39 050 313011 • Telefax +39 050 3130300
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