Epidemiology and Management of Femoral Gunshot Fractures. Our Experience

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ABSTRACT

Introduction: Gunshot injuries affect the civilian population with increasing frequency. 57% of the patients present bone compromise, with femur fractures being the most common. The lack of a standardized protocol for its treatment prompted the development of this study. **Materials and Methods:** A retrospective, descriptive study was conducted. Patients with femur fractures caused by firearms between 2019 and 2021 were included. The anatomical region, classification, treatment, and complications were analyzed. **Results:** Of a total of 35 patients, 25 (71.43%) had complete fractures and 10 (28.57%) had incomplete fractures. The distal femur was the most affected area (48.57%), according to the location. Reduction and osteosynthesis were used to treat 26 patients, with 9 being treated noninvasively. **Conclusions:** We used a simple classification system to categorize fractures as complete or incomplete. All complete ones were deemed unstable regardless of location, and all incomplete ones were deemed stable, with the exception of those in the proximal third, for which prophylactic fixation is advised. Incomplete shaft fractures can be treated noninvasively, but complete shaft fractures require reduction and osteosynthesis. For zone I and II fractures, the intramedullary nail is the preferred treatment. In zone III, an individualized analysis is required for each pattern. We believe that the initial management and the correct selection of the implant according to the affected area are decisive factors in achieving satisfactory outcomes.
Keywords: Firearm; femur fracture; epidemiology; classification.
Level of Evidence: IV

Epidemiología y manejo de las fracturas de fémur por arma de fuego. Nuestra experiencia

RESUMEN

Introducción: Cada vez con más frecuencia, la población civil sufre lesiones por proyectil de arma de fuego. El 57% de los pacientes presenta compromiso óseo y la fractura de fémur es la más común. La elevada incidencia y la ausencia de un protocolo estandarizado para su tratamiento motivaron este estudio. **Materiales y Métodos:** Estudio retrospectivo, descriptivo. Entre 2019 y 2021, se incluyeron pacientes con fracturas de fémur causadas por arma de fuego. Se analizaron las siguientes variables: región anatómica involucrada, clasificación, tratamiento y complicaciones. **Resultados:** La muestra incluyó a 35 pacientes, 25 (71,43%) con fracturas completas y 10 (28,57%), con fracturas incompletas. Según la localización, el fémur distal fue la zona más afectada (48,57%). Veintiséis pacientes fueron tratados mediante reducción y osteosíntesis y 9, de forma incruenta. **Conclusiones:** Recurrimos a una clasificación sencilla que divide a las fracturas en completas o incompletas. Todas las fracturas completas se consideraron inestables independientemente de su localización; y las incompletas, estables, salvo las del tercio proximal, donde es conveniente realizar una fijación profiláctica. Las fracturas diafisarias incompletas pueden tratarse de forma incruenta y todas las fracturas completas se trataron con reducción y osteosíntesis. El clavo endomedular es el método de elección para las fracturas en las zonas I y II. En la zona III, se requiere un análisis individualizado para cada patrón. Creemos que el manejo inicial y la correcta selección del implante según la zona afectada son factores determinantes para lograr resultados satisfactorios.
Palabras clave: Arma de fuego; fractura de fémur; epidemiología; clasificación.
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INTRODUCTION

Injuries to civilians by firearm projectiles are becoming increasingly common and the major reasons are collective conflicts, violence, crime, or terrorism. They are more common in men and the average age is 32 years, this implies a very large economic impact.[1]

Limb involvement is common, and 57% of patients who sustain non-fatal gunshot injuries have skeletal involvement, with femur fracture being the most common.[2]

To classify gunshot fractures of the femur, universally accepted systems are used. Regardless of the size of the wound, they are included in type III of the Gustilo and Anderson classification.[3] This classification has been questioned, since it does not contemplate the damage caused by the projectile, since the main prognostic factor is the energy dissipated to the tissues. For its part, the classification system proposed by the *Orthopaedic Trauma Association* evaluates the involvement of the integuments, the degree of contamination, vascular injury, and bone loss, generating an order of severity of increasing rank. However, the ideal way to use this scheme has not yet been determined, and it is currently used only in conjunction with other popular classifications.[4,5]

The primary goal of treatment is to reduce the possibility of complications and restore function to the damaged limb. Despite the fact that gunshot fractures are common, there is still controversy about the management of prophylactic antibiotic treatment and, in many trauma centers, there are still no established protocols.[6]

At present, intramedullary nailing is the definitive treatment of choice for diaphyseal fractures in adults, its benefits include less exposure and aggression to the soft tissues.[7] Supracondylar fractures with metaphyseal comminution represent a challenge. In order to determine the best fixation method, numerous biomechanical studies have been carried out to find out which is the most stable configuration.[8] As the fracture approaches neighboring joints, treatment options increase, as do complications. A comminuted gunshot fracture of the femoral neck in a young patient is a rare and potentially devastating injury. Lead toxicity and contaminants increase the risk of nonunion, avascular necrosis, septic arthritis, and joint surface damage.[9]

The high incidence of gunshot wounds in our environment and the lack of a standardized protocol for their treatment motivated this study.

OBJECTIVE

To analyze the epidemiology of femoral gunshot fractures, describe our treatment protocol and communicate the results obtained.

MATERIALS AND METHODS

A retrospective, descriptive study was carried out between 2019 and 2021 that included all patients admitted to our hospital with femoral fractures caused by gunshots.

The variables to be analyzed were collected from the records of our hospital: age, sex, anatomical region involved, classification, initial and definitive treatment. Complications were also analyzed: associated neurovascular injury, osteomyelitis, septic arthritis, pseudarthrosis, and joint stiffness.

Orthopedic evaluation and management were performed after treating immediate danger conditions following the *Advanced Trauma Life Support* (ATLS) guidelines and included systematic inspection of each limb and neurovascular examination. After initial evaluation, control of bleeding, administration of tetanus toxoid, and prophylactic antibiotics (cefazolin 2 g every 8 hours plus gentamicin 240 mg/day for 72 hours), wounds were dressed with sterile bandages and injured limbs were immobilized with splints.

The "injury-antibiotic time" was defined as the time elapsed from the initial injury to the administration of the first dose of antibiotic. The patients were divided into three groups according to the time of the first dose: group 1, early dose, before 30 min; group 2, intermediate dose, between 30 and 180 min, and group 3, late dose, after 180 min.

After diagnosis, the femur was divided into three zones based on clinical and radiological examinations to illustrate the risk of joint involvement. Zone I (hip at risk) includes fractures of the femur proximal to the distal end of the lesser trochanter. Zone II (femoral shaft) is defined as a fracture distal to the distal end of the lesser trochanter and proximal to the distal diaphyseal-metaphyseal junction. Zone III (knee at risk) includes fractures below the distal metaphyseal diaphyseal junction.

To assess bone involvement, the fractures were classified as complete or incomplete according to the radiological continuity of the cortices. When the projectile trajectory resulted in the integrity of at least one cortex, they

were called incomplete fractures. The OTA/AO classification was also used, but we did not rely on it to define therapeutic choices.

Computed tomography was only requested in patients with complex patterns to achieve a better visuospatial characterization or assess joint involvement.

Following the protocol guidelines of our institution for the initial management of open fractures, all patients underwent mechanical-surgical debridement, profuse washing with physiological solution, superficial debridement of devitalized tissue with primary closure of the wound without tension, and stabilization with an external fixator in the case of complete fractures, restoring the length, alignment and rotation of the limb and thus allowing appropriate soft tissue control. This constituted one of the pillars of treatment.

In cases of extensive contamination, torpid evolution of the wound or early signs of phlogosis, the wound was explored 48-72 h later and the sample was taken for microbiological culture.

The following factors were considered when deciding on the definitive treatment: the anatomical position with respect to the damaged area, the type of fracture, and the integrity of the cortices.

Noninvasively treated incomplete fractures required close follow-up. After 45 days, as tolerated, partial weight bearing was advised, with weekly radiological controls during the first month and subsequently every 15 days until signs of bone consolidation were observed.

RESULTS

The sample consisted of 35 patients: 33 men (94.29%) and two women (5.71%), with a mean age of 31.5 years (range 16-59).

Taking into account the classification of the fractures, 25 (71.43%) were complete and 10 (28.57%), incomplete (Figures 1 and 2). Eight (22.86%) had only an entry orifice and 27 (77.14%) had an associated exit orifice.

Figure 1. Distal femur radiographs, anteroposterior (**A**) and lateral (**B**). Incomplete fracture of the distal femoral metaphysis, a characteristic pattern described by Smith as a "drill hole".

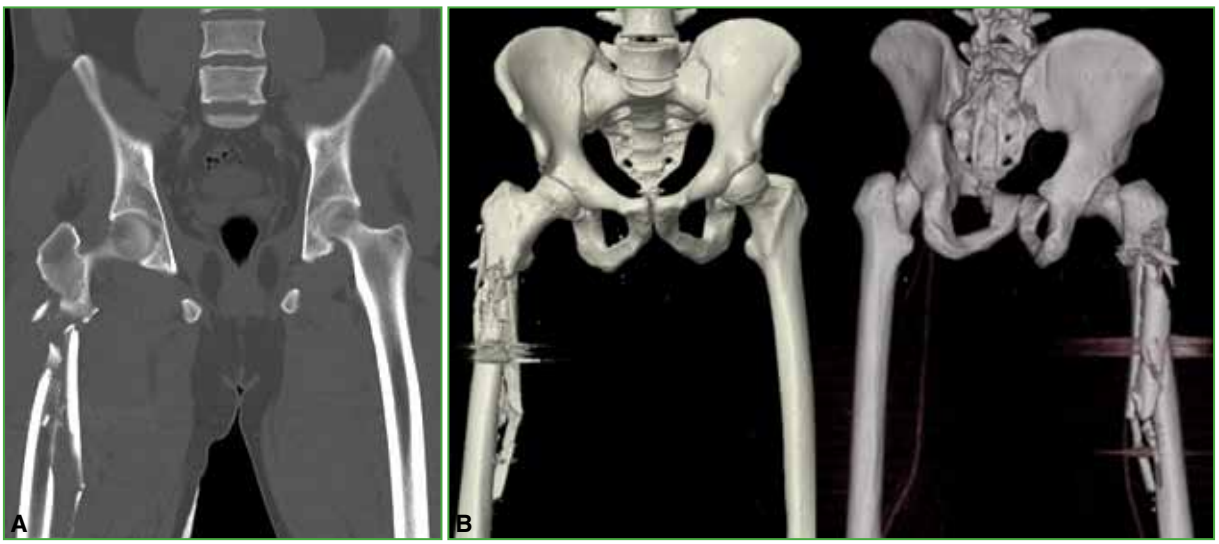

Figure 2. M28, complete multifragmentary fracture of the right femur. **A.** Computed tomography of the pelvis and femur, 2D coronal section. **B.** 3D reconstruction. Fracture of the proximal femur with diaphyseal extension.

According to the location, the lesion was located in zone I, in three patients (8.57%); in zone II, in 15 patients (42.86%) and, in zone III, in 17 cases (48.57%) (Figure 3). The distribution of complete and incomplete fractures in relation to the affected area is shown in Figure 4.

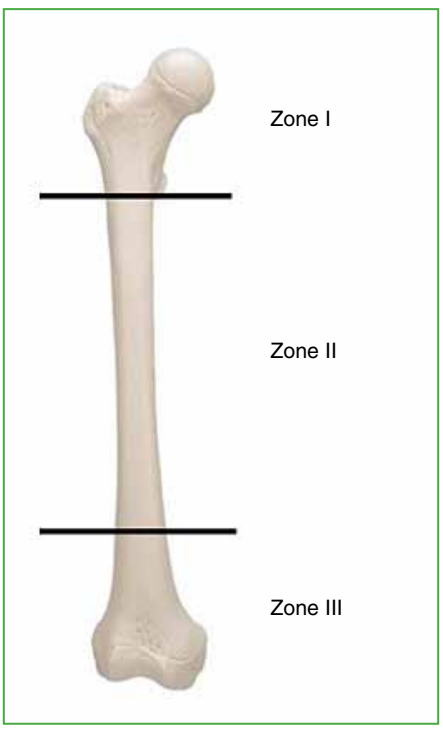

Figure 3. Division of the femur into zones and distribution of injuries according to incidence.

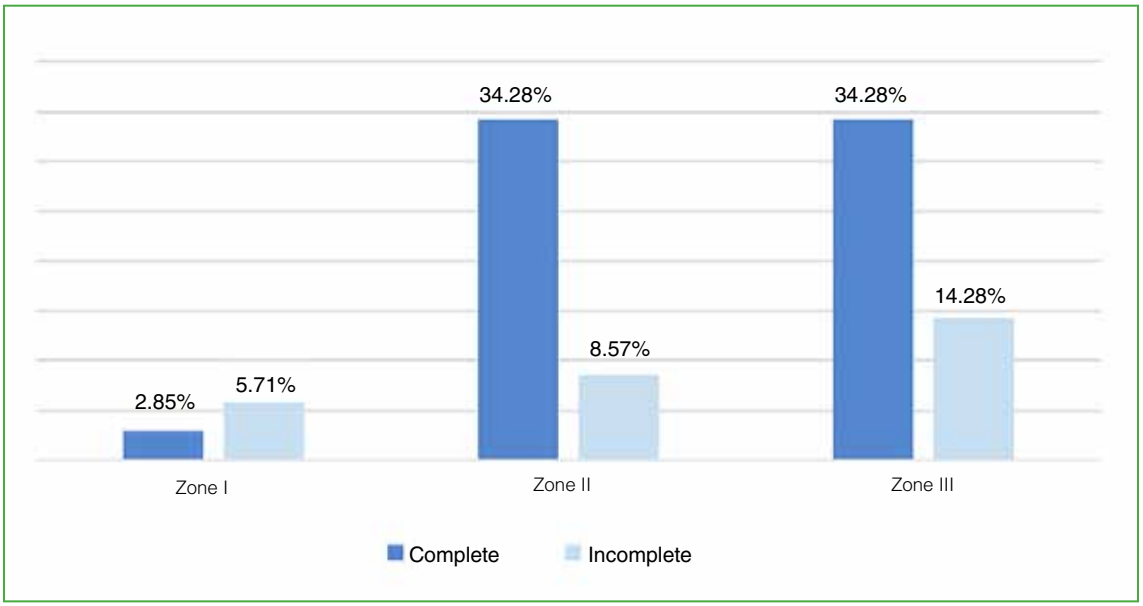

Figure 4. Type of fracture according to location.

Regarding the initial treatment, the patients with complete fractures (71.43%) were stabilized with an external fixator (Figure 5). Patients with incomplete fractures in zone I (5.71%) were prescribed strict bed rest, while those with fractures in zones II or III (22.85%) were immobilized with a plaster cast. In terms of "lesion-antibiotic time," 14 patients in group 1 (40%), 16 in group 2 (46%), and 5 in group 3 (14%), received a first early dose.

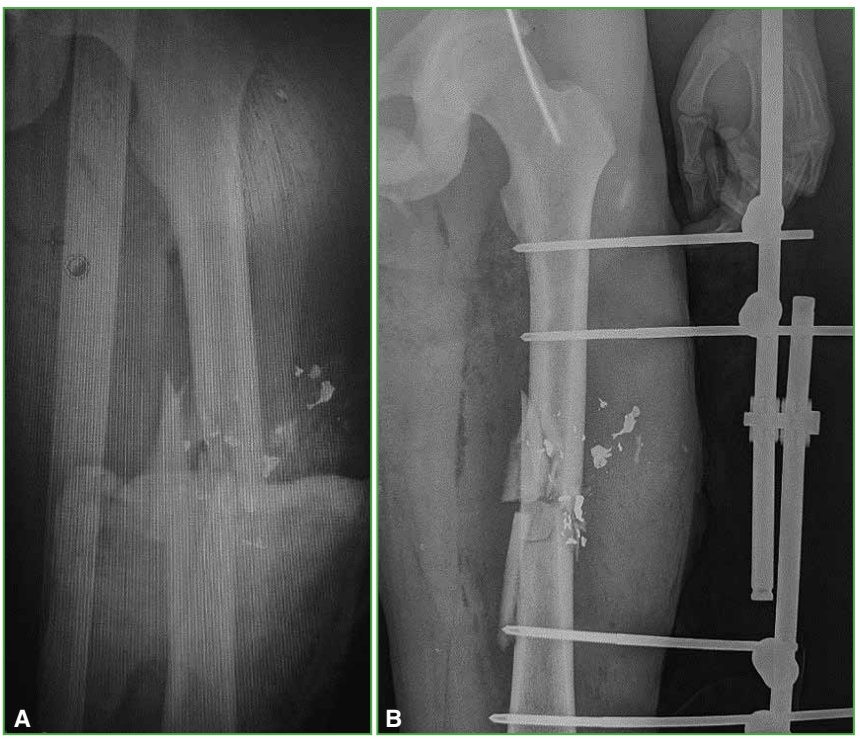

Figure 5. A. Anteroposterior radiograph of a complete fracture of the femur in zone II. **B.** Stabilization with an external fixator.

Regarding the definitive treatment, all the patients with complete fractures were treated by reduction and osteosynthesis, only one with an incomplete fracture underwent prophylactic fixation due to its location in zone I.

The fixation methods used were distributed as follows: 19 (54.29%) with intramedullary nailing (Figures 6 and 7) and seven (20%), which compromised zone III, with anatomic locking plates.

Figure 6. A. Distal femur, anteroposterior and lateral radiographs. Complete comminuted fracture of the left femur in zone III. **B.** Soft tissue with entry and exit orifices. **C.** Stabilization with external transarticular fixator. **D.** Anteroposterior and lateral radiographs. Immediate postoperative period.

Figure 7. Surgical resolution using a cervicodiaphyseal nail in the patient in Figure 2. **A.** Anteroposterior and lateral ankle radiographs (**B**).

Noninvasive management was chosen in nine patients with incomplete fractures (Figure 8).

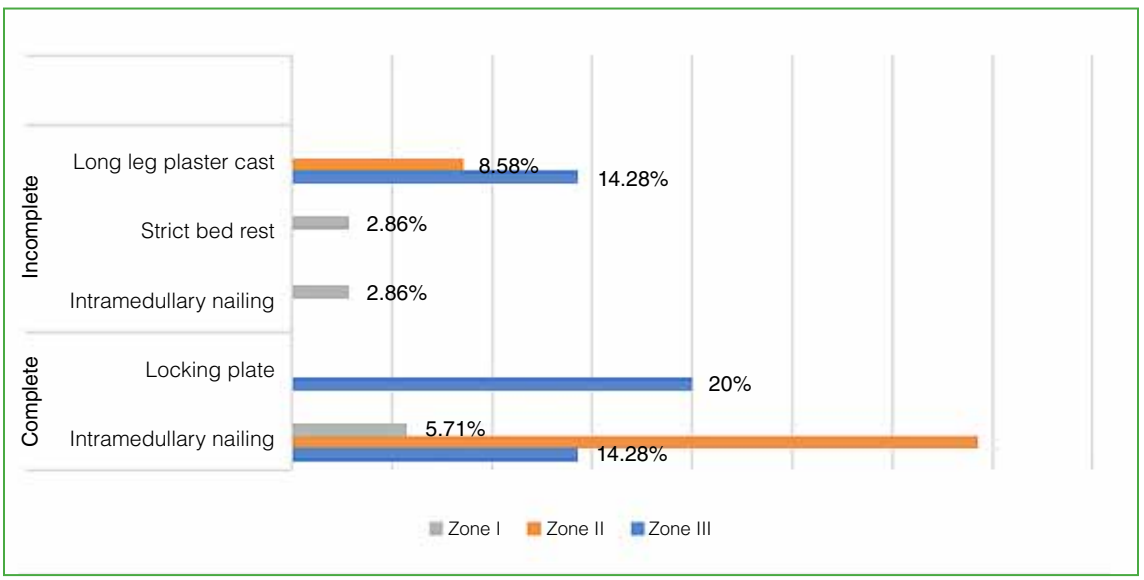

Figure 8. Definitive treatment according to the location and type of fracture.

Complications were: osteomyelitis (1 case; 2.86%), septic arthritis (1 case; 2.86%), pseudarthrosis (2 cases; 5.71%), one (2.86%) patient with complete fracture in Zone III developed a vascular lesion that required revascularization on admission. A fracture treated noninvasively with a long leg plaster cast evolved with joint stiffness of the knee (Table).

The mean follow-up was 15 weeks (range 3-38), only 55% of the patients attended their control at three months. The remaining 45% had a mean follow-up of 8 weeks (range 3-11).

Table. Rate of complications according to anatomical distribution and classification of fractures.

Complication	Fracture type	Classification OTA/AO	Affected zone	Rate
Osteomyelitis	Incomplete	32 B3	Zone II	n = 1 (2.86%)
Infected pseudarthrosis	Complete	32 C3/A2	Zone II/ III	n = 2 (5.71%)
Septic arthritis	Complete	33 C1	Zone III	n = 1 (2.86%)
Vascular injury	Complete	33 C2	Zone III	n = 1 (2.86%)
Joint stiffness	Complete	33 C3	Zone III	n = 1 (2.86%)

DISCUSSION

Ballistic trauma to the musculoskeletal system is a prevalent and growing concern; nonetheless, it is a little-studied injury. According to published articles, 91% of patients are young men.[10,11] In our study, the mean age was 31.5 years and 94.29% were men.

Long bone fractures are the most common orthopedic injuries and are classified as grade IIIA by Gustilo and Anderson as fractures caused by high-energy mechanisms with adequate tissue for coverage. This classification is simple, reproducible and adaptable to the population studied.[3]

The level of damage in gunshot wounds is determined by the distance from the target, the muzzle velocity, and the projectile's properties and caliber. In the civilian population, they are produced, to a large extent, by high-velocity, low-caliber weapons.[12] However, they determine a wide variety of injuries, from a fracture with great bone compromise to a partial fracture with continuity of its cortices. We found fracture patterns that were not fully applicable to the OTA/AO classification, so we resorted to a simple classification described in 1984 by Smith and Wheatley[13] who studied firearm fractures and divided them into complete or incomplete.

In our study, most of the incomplete fractures corresponded to the metaphysis; those located in zone I were considered risky or potentially unstable lesions due to the risk of collapse or extension of the fracture line with subsequent displacement.[14] Complete Fractures represented the predominant pattern in our study (71.48%), which coincides with what was published by Nguyen et al.[15] and all were considered unstable regardless of their location.

Regarding the initial management of these injuries by small-caliber firearms, Sathiyakumar et al.[16] recommend prophylactic antibiotic therapy and superficial debridement of the wound instead of exhaustive debridement to prevent the development of infectious processes. It has also been shown that, in Gustilo type IIIA fractures, infection rates are lower with primary wound closure than with delayed closure, 4% and 17.8%, respectively.[17] All the patients in our series were treated with superficial debridement and primary closure. If a high degree of contamination was detected, greater involvement of the soft tissues, or unfavorable evolution of the wound, deep surgical debridement was performed 48–72 hours later with sample collection for culture.

In complete fractures caused by firearms, due to their high energy, stabilization is a basic principle of treatment. Therefore, external fixation was part of our initial management. The definitive stabilization method was selected on the basis of the location and the degree of compromise and integrity of the cortices. Incomplete fractures of the proximal femur require prophylactic fixation due to stress or compression vectors that are likely to result in future extension of the fracture line.[13]

In our series, there were three fractures of the proximal femur, two of them were incomplete, only one was treated by prophylactic stabilization with cephalomedullary nailing. The other patient was treated with rest and off-loading for 45 days; in this case, the delay in the availability of surgical material represented a limitation for the choice of treatment. The rationale for surgical treatment in these patients is to perform a simple procedure and allow immediate weight-bearing and prevent a complex future procedure in the event of fracture collapse or displacement.

Incomplete fractures of the middle third can be treated noninvasively with a limited period of off-loading.[18] The three patients in our series were treated by immobilization with a long leg plaster cast and off-loading. All zone II complete fractures were treated with reduction and osteosynthesis with locking intramedullary nailing.

Currently, the retrograde or antegrade intramedullary nail is the method of choice for the resolution of femoral gunshot fractures.[19] In a systematic review, an overall rate of 0.18% of septic knee arthritis was found after retrograde intramedullary nail fixation.[20] The only case with this complication was a patient with a supracondylar fracture treated with retrograde intramedullary nailing.

The failure rate of retrograde nailing in distal femur fractures reaches 38% of cases, while the failure rate after osteosynthesis with LISS plate (*less invasive stabilizing system*) reaches 20%.[21]

Delayed union and nonunion may be related to the amount of bullet material retained near the fracture site, due to the cytotoxic effect of lead.[22] We believe that further studies are needed to demonstrate that removal of extra-articular impacted fragments outweighs the risk of inducing iatrogenic soft tissue damage. Our practice is to remove extra-articular bullet remnants only if they are accessible during initial superficial debridement, while we always remove intra-articular remnants (hip or knee), preferably arthroscopically.

Of the two fractures that evolved to pseudarthrosis (5.71%), one corresponded to zone II and the other to zone III. The first was treated with reaming of the canal and replacement of the nail with a larger diameter one, and radiographic signs of consolidation were observed at 14 weeks, while the second case was initially treated with retrograde intramedullary nailing as the only fixation method and later it was necessary to add a locking plate during surgical revision to achieve consolidation at 18 weeks. We believe that, in zone III fractures treated only with intramedullary nailing, insufficient distal locking and not using post screws are determining factors in the outcome. No retained bullet remains were detected in the radiographs or during surgery in either of these two cases.

Gunshot wounds to the extremities are associated with vascular injury in 10-17% of cases.[23] In our study, the percentage was 2.86%, since we limited ourselves to analyzing only femur fractures.

On the other hand, the osteomyelitis rate for Gustilo III high-energy femur fractures ranges from 3.3% to 4.2%.[24] One case (2.86%) of acute osteomyelitis confirmed by the isolation of methicillin-resistant *S. aureus* was detected in all bone samples taken during exploration of a wound with poor evolution. It was successfully treated with intramedullary nailing coated with polymethylmethacrylate with vancomycin plus targeted intravenous antibiotic therapy.

Regarding the time of antibiotic administration and the development of infectious complications (septic arthritis, 1 case; osteomyelitis, 1 case), the patients belonged to group 2 and group 3, respectively.

Johnson et al.[25] reported that patients with gunshot wounds do not comply with follow-up; in our study, only 55% attended their check-up at three months. The remaining 45% had a mean follow-up of two months (range 3-11 weeks). We believe that the main factors associated with incomplete follow-up could be age, short hospitalization, and non-compliance with medical instructions in the population studied.

The limitations of this study include its retrospective nature, and we believe that the absence of continuity in the follow-up of these patients made analyzing the problems in the medium and long term difficult.

CONCLUSIONS

90% of the patients in our series had involvement of zones II and III, so zone I was an infrequent region for this condition. For incomplete fractures in this area, prophylactic fixation is recommended.

Intramedullary nails are the best option for complete fractures in zones I and II, while in zone III, an individualized analysis of each pattern is required to choose the fixation method.

We believe that the early administration of antibiotics in the initial management and the correct selection of the final implant according to the affected area are essential to achieve good outcomes.

Conflict of interest: The authors declare no conflicts of interest.

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