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**Case Report**

# Bent intramedullary femoral nail: a rare injury following high-energy trauma

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## Abstract

High-energy trauma may result in catastrophic orthopedic injuries, particularly in patients with existing long bone implants. Peri-implant fractures pose unique mechanical and biological challenges, especially when implant integrity is compromised. We report a rare case of a young adult with a previously healed femoral shaft fracture treated with an antegrade intramedullary nail. Following a motor vehicle accident, the implant experienced severe axial deformation, with associated new fractures at the midshaft and distal femur. Despite undergoing emergency interventions, the patient succumbed due to multisystem trauma. This case illustrates a rare mechanical failure where the intramedullary nail's structural limits were exceeded. Radiological and biomechanical analysis provides insights into the forces involved and the potential need for implant redesign in high-risk trauma settings.

**Keywords:** High-energy trauma, bent, femoral fracture, intramedullary nail, deformation, peri-implant fracture

## Introduction

Femoral diaphyseal fractures are serious orthopedic injuries frequently encountered in high-energy traumas and require effective treatment [1,2]. In modern orthopedic surgery, intramedullary nails (IMNs) are widely used in the management of these fractures [1,2]. IMN systems are preferred due to their minimally invasive nature, their ability to provide axial and rotational stability from a biomechanical standpoint, and their facilitation of early mobilization. Currently, IMN fixation is considered the gold standard treatment for femoral diaphyseal fractures [1-6]. These nails are typically manufactured from titanium or stainless steel alloys and are capable of withstanding axial loads up to 4000 N and torsional forces ranging from 80 to 120 Nm [2-5]. Their fatigue resistance corresponds to approximately one million loading cycles, which is equivalent to the average mechanical loading corresponding to typical daily activities in a healthy adult [2-5]. However, even these robust systems may fail mechanically under extreme conditions, particularly in the setting of high- energy trauma.

In this study, we present a case of femoral segmental fracture and bent nail in the femur intramedullary as a result of high-energy injury.

## Case report

A 24-year-old male patient was brought to the emergency department of our hospital by ambulance following a motor vehicle accident and was referred to our clinic due to multiple extremity fractures. Initial evaluation after emergency interventions and imaging revealed a critically ill, intubated patient with a Glasgow Coma Scale (GCS) score of 3, blood pressure of 60/30 mmHg, and heart rate of 140 bpm. Findings were consistent with multisystem trauma. Emergency imaging demonstrated stable fracture lines at the C2, T2, and T8 vertebrae. Both lungs appeared expanded on radiographs. A right-sided pneumothorax and a left-sided hemopneumothorax were identified, and tube thoracostomies were performed by the thoracic surgery team. Contrast-enhanced computed tomography (CT) revealed a transection of the thoracic aorta. From an orthopedic perspective, evaluation of suboptimal emergency radiographs revealed a Gustilo-Anderson type 3C open fracture of the left femoral diaphysis, a type 3A open fracture of the left tibial plateau, a fracture of the left lateral malleolus, and a previously implanted antegrade femoral intramedullary nail in the right femur (inserted in 2017), which was found to have undergone approximately 35° degrees of bending due to

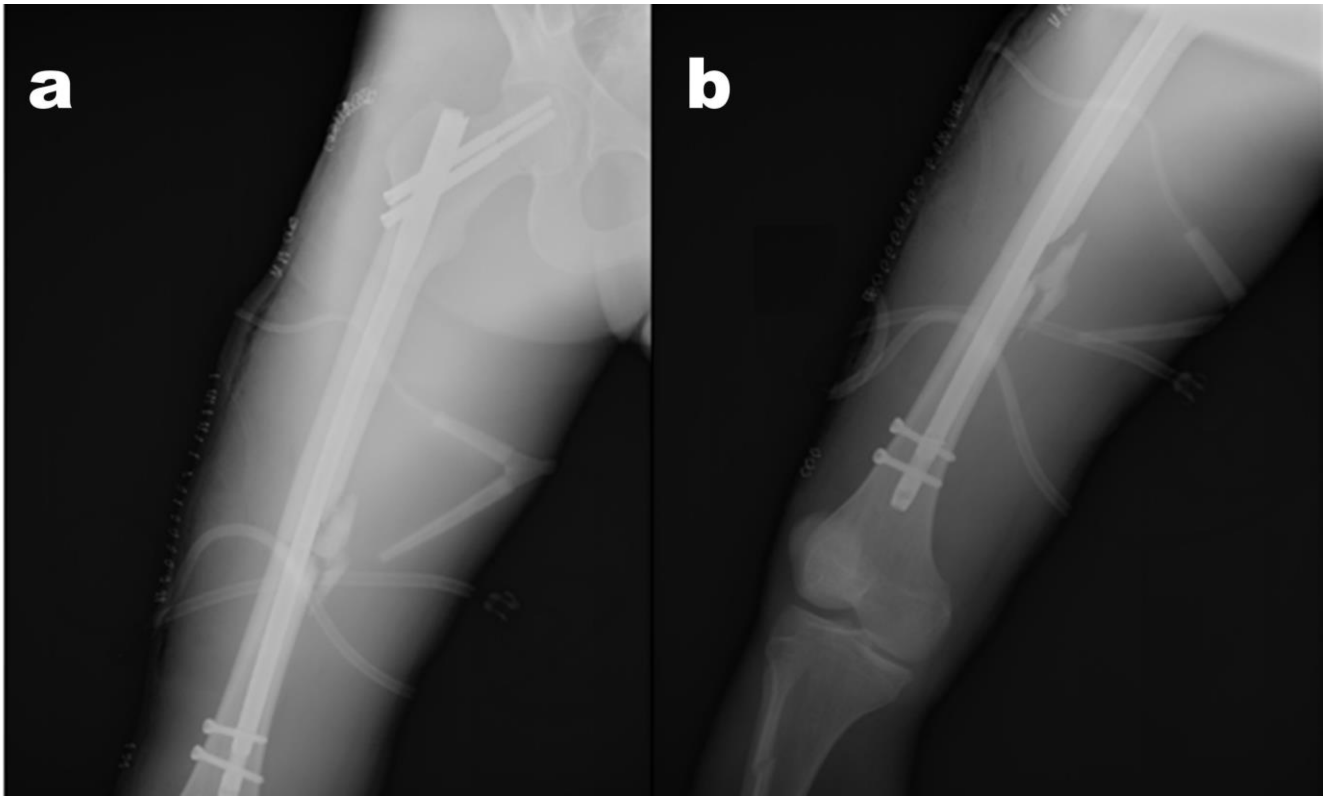


**Figure 1**. **a, b)** Postoperative femur radiographs of the patient taken before the traffic accident.

the high-energy impact. Additionally, fractures were observed both at the site of the nail deformation and at its distal tip. The open wounds were irrigated with sterile saline solution, and long leg splints were applied to both lower extremities. Despite responding to cardiopulmonary resuscitation (CPR) in the emergency department resuscitation room, the patient experienced a total of four cardiac arrests and was ultimately deceased.

## Discussion

Traffic accidents represent one of the most dramatic sources of trauma, involving the rapid transfer of high kinetic energy to the human body [1-7]. In this case, the patient's arrival to the emergency department in an intubated state, with a Glasgow Coma Scale (GCS) score of 3, hypotension, and tachycardia, clearly illustrates the severity of the systemic trauma. The presence of a thoracic aortic transection, bilateral hemopneumothorax, and multiple vertebral fractures, as identified by computed tomography, further highlighting the extent of injury.

In such cases of polytrauma, it must be emphasized that orthopedic injuries should be assessed within a multidisciplinary framework, considering life-threatening systemic injuries as a priority [3-8]. In patient, the presence of severe implant deformation despite the structural integrity of the previously placed intramedullary nail—even in a young individual—underscores the magnitude of the trauma [1-8].

Management of such fractures should be planned once the patient's general condition has stabilized [6,7]. However, in cases like this, where simultaneous multi-organ injuries and hemodynamic instability are present, orthopedic intervention is typically limited to a damage control approach [10-12]. Temporary stabilization techniques such as splinting or external fixation are prioritized with the primary goal of preserving life [1-3].

Antegrade femoral intramedullary nails have been successfully used for many years, particularly in the treatment of diaphyseal fractures [13-15]. Nowadays, these nails are predominantly manufactured from titanium alloys due to their lightweight nature and favorable biomechanical strength [1-15]. Titanium intramedullary nails are reported to have a lower modulus of elasticity compared to stainless steel nails, allowing for more physiological load transfer to the bone [13-15]. This results in a reduction of the stress shielding effect and contributes to improved fatigue resistance [10-15]. Furthermore, titanium offers superior biocompatibility, reducing the risk of adverse tissue reactions when compared to stainless steel, thereby enhancing long-term implant stability [2].

Titanium alloys exhibit lower stiffness but also higher strength compared to stainless steel, with a Young's modulus of approximately 105–120 GPa and a yield strength ranging from 800 to 950 MPa. In contrast, 316L stainless steel has a Young's modulus of 190–210 GPa and a yield strength of 500–700 MPa [10-12]. Femoral intramedullary nailing (IMN) systems can be inserted using either a reamed or unreamed technique and typically achieve stability through proximal and distal interlocking [10-12]. Reamed systems allow for the insertion of thicker nails and provide better contact with the cortical bone, offering superior biomechanical fixation [10-12].

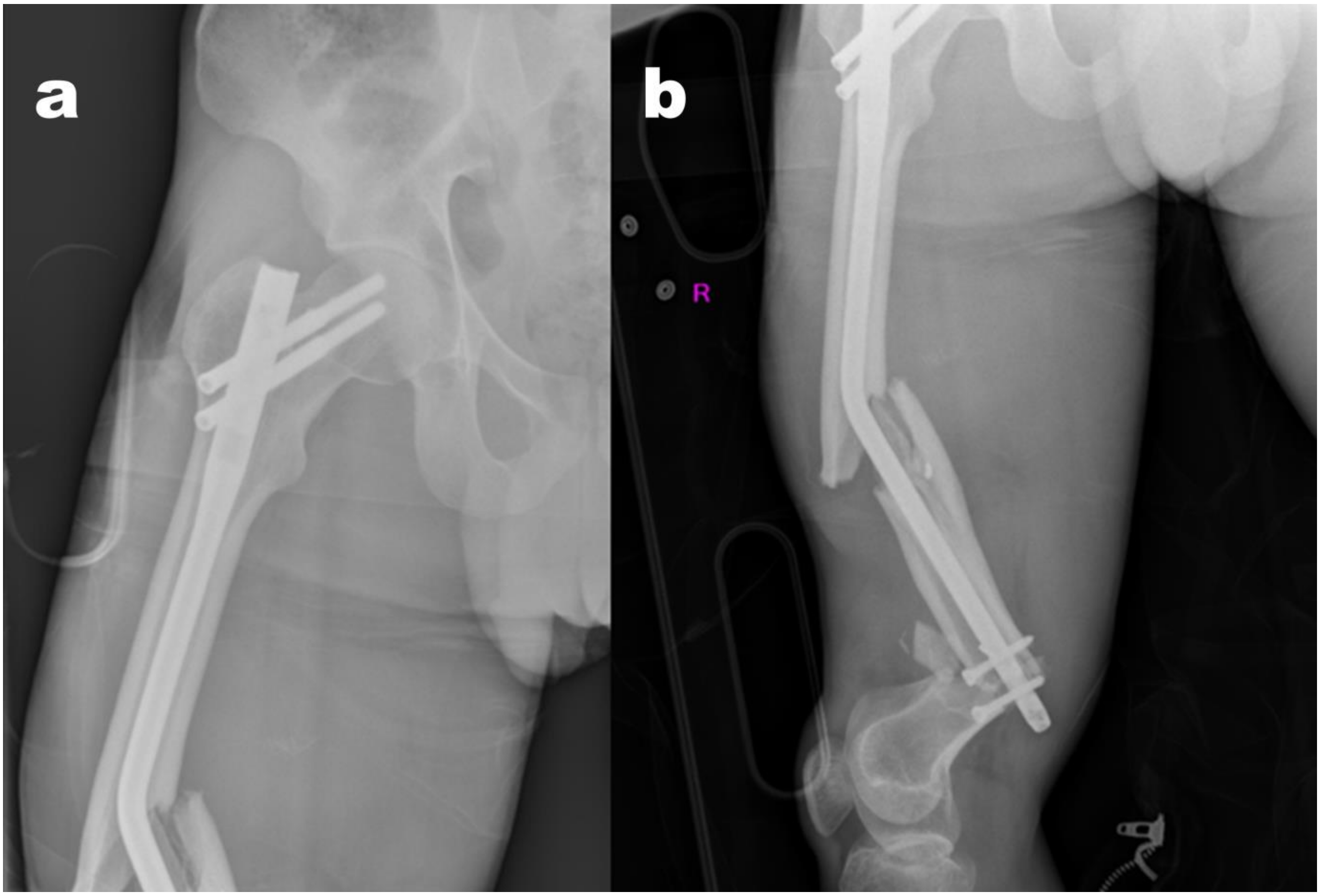


**Figure 2. a, b)** The severity of the trauma on the post-traumatic radiographs of the patient, and the appearance of the abnormal angular deformity that developed with the implant in the femur.

Therefore, reamed nailing is preferred in diaphyseal femoral fractures due to its enhanced torsional and axial strength [6].

Studies have demonstrated that locked intramedullary nails are superior to unlocked systems, particularly due to their ability to enhance rotational stability and prevent displacement in long spiral or segmental fractures [7]. However, the success of intramedullary nails is not solely dependent on factors such as material composition, reamed versus unreamed technique, or the use of locking mechanisms; it is also directly influenced by the severity of the trauma and the biomechanical loading patterns [7-12]. The occurrence of a new fracture in a femur previously treated with an intramedullary nail—where the nail remains intact but undergoes significant deformation—is a rare yet clinically significant scenario in orthopedic practice [7-12]. In some cases, the bone segment containing the implant may become mechanically weaker than a native femur [6,10]. Cortical thinning may occur due to stress shielding around the implant [10-12]. Moreover, the ends of the nail often act as stress risers, where the energy from trauma is concentrated, making these transition zones the most common sites for fracture propagation [10-12]. The newly introduced kinetic energy may exceed the elasticity of the bone–implant construct, resulting in both implant deformation and fracture of the surrounding bone [13-15]. The most striking finding in this case is the development of axial bending deformation in an implant that had previously stabilized and fully healed the femur [10,15]. The point of bending occurred at the mid-diaphyseal region—the mechanically weakest segment of the construct [10,15]. The most likely explanation for this is that the high-energy trauma was applied directly to the femur along a perpendicular axis, and the resulting force exceeded the elastic limits of the intramedullary nail [9-15]. In this case, the antegrade intramedullary nail sustained a 35° deformation at the mid-diaphyseal (middle 1/2) level and also caused a separate fracture at the distal tip of the nail. Imaging findings revealed that the nail had undergone both elastic and plastic deformation, resulting in permanent structural alteration. Previous biomechanical studies have reported that femoral nails can withstand approximately 4000 N of axial loading, beyond which permanent plastic deformation begins [8,12].

It has also been documented that, particularly during high-energy motor vehicle collisions, axial forces exceeding 10,000 N can be exerted on the body at the moment of impact [8-12]. While such deformation is theoretically possible, clinically observed dramatic structural alterations in intramedullary nails of this magnitude remain extremely rare [13,14]. Femoral intramedullary nails are also subjected to various torsional forces during both physiological and traumatic loading [13-14]. It has been reported that these nails can typically withstand torsional stress in the range of 10–20 Nm during normal ambulation, and up to 40–80 Nm during high- energy activities such as running or jumping [5,7,9]. The threshold for failure or permanent deformation has been shown to range between 120–150 Nm [5,7,9].

In high-energy trauma scenarios, the most commonly observed complications include implant fracture or failure of the interlocking screws; however, elastic deformation of this degree is exceedingly rare. In the present case, although the structural integrity of the nail remained intact, a significant shaft deformation occurred [8-15]. Such deformation may directly compromise both the rigidity of the implant and the biomechanics of load transfer [5,7,9,12].

Removal of a bent intramedullary nail can be a technically challenging surgical procedure [3-5]. The available literature on the removal of a bent intramedullary femoral nail describes several different techniques, including various techniques for trimming the intramedullary nail [3-5]. While no single method has been proven superior to another, algorithms developed for each removal method may be helpful [3-5].

Although the patient's death was not directly attributable to the nail deformation, the presence of such implant failure should be considered during both trauma assessment and surgical planning [12-15]. This case dramatically illustrates how a femur previously treated with an antegrade intramedullary nail can sustain significant damage under high-energy trauma, resulting in both implant deformation and disruption of bone integrity. It highlights the potential for failure even in femora that have previously healed and been stabilized with intramedullary fixation when subjected to extreme axial loading [7,8].

This study clearly demonstrates how the biomechanical limits of the bone–implant construct can be exceeded in high-energy traumaCases similar to this one have rarely been reported. The presented study is comparable to those described in a 2020 systematic review by Dunleavy et al. [15], which included 27 cases of bent femoral intramedullary nails. In that review, the mean angle of deformation reported was 35.6°, which closely aligns with the 35° deformity observed in our patient [15]. Additionally, as noted in the same study, our patient also experienced both angular deformation of the existing nail and a new fracture at the same location following a second high-energy trauma. Considering these similarities, the presented case can be regarded as one of the rare but clinically significant complications previously described in the literature [2-5,14].

In conclusion, this case demonstrates that a femur previously stabilized with an intramedullary nail can sustain a new fracture with significant implant deformation—even in a young patient with a fully healed initial fracture—following high-energy trauma. Under extreme mechanical stress, previously implanted hardware may become the weakest structural link within the bone–implant construct.

The key conclusions to be drawn the following: High-energy traumas can cause severe deformities and fractures in bones with pre-existing implants [2-5,14]. The 35° deformation observed in the intramedullary nail represents one of the more significant cases of plastic deformation rarely reported in the literature [8,9,11,12].. From a mechanical perspective, such deformation in femoral intramedullary nails is likely to occur under axial loads exceeding approximately 4000 N, surpassing the material limits of the implant [8,9,11,12]. In addition to axial compression, torsional stress and impact forces are the primary contributors to this deformation [8,9,11,12]. In cases of multisystem trauma, achieving systemic stability prior to orthopedic fixation is of critical importance [8,9,11,12].

This study should be regarded as a representative example in the literature, highlighting both femoral intramedullary nail deformation due to high-energy trauma and the systemic management of polytrauma. It also underscores the importance of early multidisciplinary intervention in similar scenarios.

## Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by ABK, Mİ and ZK. The first draft of the manuscript was written by ABK, Mİ and ZK and all authors commented on previous versions of the manuscript. All authors read and approved of the final manuscript.

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### Conflict of Interest

The authors declare that they have no conflict of interest.

## Ethical statement

The authors confirm that this retrospective study was conducted in accordance with the ethical standards set forth in the Declaration of Helsinki and its later amendments.

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