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ORIGINAL ARTICLE

The Causes of Proximal Femoral Nail Complications

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Abstract

Introduction: We aimed to investigate the relationship between possible causes and complications after osteosynthesis with a proximal femoral nail (PFN) in patients with intertrochanteric femoral fractures.

Methods: A total of 122 patients (50 men, 72 women) who were followed for at least one year were analyzed retrospectively. The mean age of the patients was 74 (range: 24-97). The left side was affected in 73 patients, while the right side was affected in 49 patients. The causes of fractures were simple falls at home in 109 cases, falls from height in 6 patients, and traffic accidents in 7 cases. Patients underwent surgery an average of 6.2 days (range: 1–26) after the trauma. All operations were performed in the supine position under fluoroscopic control with manual traction.

Results: According to the Harris hip score, 6.6% of patients had excellent, 18% excellent, 45% good, 21.3% fair, and 9% poor results. A total of 20 infections (8 superficial, 12 deep), 22 implant failures (12 cut-out, 6 Z-effect, 4 reverse Z-effect), 3 femoral shaft fractures distal to the PFN, 2 nonunions, 1 avascular necrosis in the femoral head, 9 sacral decubitus ulcers, 1 gluteal decubitus ulcer, 1 pulmonary embolism, and 1 thromboembolism were observed. When fracture types and implant failure were compared, the highest implant failure rate was seen in Modified Evans-Jensen type 5 fractures (36.7%), but the relationship was not statistically significant ($p>0.05$). Infection developed in 8 (26.7%) of 30 patients with type 5 fractures, and this relationship was found to be significant ($p<0.05$). No statistically significant relationship was found between the presence of systemic disease, gender, age, affected side, time between trauma and surgery, mechanism of trauma, and complications.

Discussion and Conclusion: Modified Evans-Jensen type 5 fractures had the highest complication rate among intertrochanteric fractures treated with PFN. Therefore, applying the nail with proper technique and achieving acceptable reduction is essential to ensure balanced osteosynthesis in such fractures.

Keywords: Complications; intertrochanteric fracture; osteosynthesis; proximal femoral nail.

Femoral intertrochanteric fractures, frequently occurring in the elderly due to osteoporosis, remain significant today because of their high mortality and morbidity, as well as the economic burden associated with treatment and care[1-3].

Intertrochanteric fractures typically occur in young adults due to high-energy injuries, such as traffic accidents and falls from heights. In the elderly, low-energy injuries, such as simple falls, account for 90% of cases[4,5]. Factors such as the presence of systemic diseases, decreased

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protective reflexes during falls, weakened muscle strength, and deteriorating bone quality increase the risk of such fractures in advanced age[1,6]. The union rate of intertrochanteric fractures is high due to their extracapsular and cancellous structure. However, they are characterized by high mortality and morbidity, particularly in elderly patients undergoing conservative treatment, as prolonged bed rest can lead to severe complications. Therefore, mobilizing the patient as soon as possible is essential to prevent immobility-related complications. Consequently, early mobilization following surgery that ensures anatomic alignment and stable fixation is the standard approach for treating intertrochanteric fractures[7,8].

Intramedullary fixation devices have recently been preferred in intertrochanteric fractures due to their biomechanical advantages and ease of application. However, implant failures are not uncommon (4-7%), and complications such as screw cut-out, Z-effect, reverse Z-effect, peri-implant fracture, nonunion, and infection may also occur[9,10]. In this context, we applied proximal femoral nails (PFNs) to patients with intertrochanteric fractures in our clinic between 2009 and 2011, aiming to investigate the causes of the resulting complications.

Materials and Methods

The Ümraniye Education and Research Hospital Ethics Committee approved this study protocol (2018-106). Written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

PFN osteosynthesis was performed on 159 hips of 159 patients with intertrochanteric femur fractures between January 2009 and September 2011 at the Orthopedics and Traumatology Clinic of the Ümraniye Education and Research Hospital. A total of 122 patients who were followed up regularly for at least one year were retrospectively examined. Patients aged 18 years and older were included in the study. Patients with pathological fractures, those treated with a method other than PFN, and those with metabolic bone disease were excluded. The mean follow-up period was 19.2 months (range: 12–45). Fifty (41%) cases were female, and 72 (59%) cases were male. The mean patient age was 74 years (range: 24–97). In 73 patients, the left side was affected, whereas the right side was affected in 49 patients. The causes of fractures were simple falls at home in 109 cases, falls from height in 6 patients, and traffic accidents in 7 cases. One patient had a right humerus surgical neck fracture, one had a left tibia shaft fracture, and two had a left distal radius fracture. The humerus surgical neck fracture was treated with plate-screw osteosynthesis, while the tibia shaft fracture was repaired with intramedullary nail osteosynthesis. One distal radius fracture was treated with closed reduction and percutaneous K-wire osteosynthesis, whereas the other was managed with closed reduction and short arm casting.

Pelvic anterior-posterior radiographs, including both coxofemoral joints and the proximal femur, were obtained at admission. Preoperative fractures were evaluated according to the Modified Evans-Jensen classification[11]. Accordingly, 20 patients had type 1 fractures, 32 had type 2 fractures, 15 had type 3 fractures, 25 had type 4 fractures, and 30 had type 5 fractures (Table 1). Table 2 shows the accompanying internal pathologies.

The patients' preoperative risk assessment was performed by the Anesthesia and Reanimation Clinic according to the American Society of Anesthesiologists (ASA) criteria[12]. Of the 122 patients, 58 (47.5%) were classified as ASA-1, 35 (28.6%) as ASA-2, 28 (22.9%) as ASA-3, and 1 (0.8%) as ASA-4.

All patients received subcutaneous 0.4 mL enoxaparin sodium once daily from admission until discharge. Prophylaxis was continued for another 35 days after discharge. All patients received intravenous 1 g cefazolin sodium one hour before surgery for infection prophylaxis, which was continued for 48 hours postoperatively, three times a day. Patients underwent surgery an average of 6.2 days (range: 1–26) after the trauma.

All patients were operated on in the supine position, and reduction was performed in a closed manner. Since our

Table 1. Number of cases according to modified Evans Jensen classification

Fracture Type	n	%
Type 1	20	16.3
Type 2	32	26.2
Type 3	15	12.3
Type 4	25	20.5
Type 5	30	24.6

Table 2. Concomitant internal pathologies of the cases

Internal Pathologies	n	%
Chronic Heart Disease	46	37.7
Chronic Nervous System Disease	11	9.0
Diabetes mellitus	18	14.8
Chronic Lung Disease	9	7.4
Chronic Renal Failure	2	1.6

hospital lacked a traction table, traction was provided and maintained manually by an assistant. Fluoroscopy control was performed at every stage of the surgery, and the proximal femoral nail was applied according to the surgical technique. General anesthesia was administered to 62 patients (50.8%), whereas spinal anesthesia was used in 60 patients (49.2%). The mean hospitalization duration was 4.5 days (range: 1–68). Sutures were removed on the 15th postoperative day.

Isometric hip and knee exercises were initiated on the first postoperative day for all patients, who were seated on the edge of the bed with the assistance of a physiotherapist and a doctor. Mobilization with partial weight-bearing using a walker was allowed for six weeks, followed by full weight-bearing after six weeks. Radiographic controls were performed on the 15th postoperative day and at the 3rd, 6th, and 12th months. During these evaluations, position stability, implant failure, and union status were assessed. Additionally, the Harris Hip Scoring System was used to evaluate the patients' functional status after surgery.

Statistical Analysis

The statistical software Number Cruncher Statistical System (NCSS) 2007 (Utah, USA) was used for statistical analysis. A $p<0.05$ was considered statistically significant.

Results

According to the Harris Hip Score criteria, 8 patients (6.6%) had excellent results, 22 patients (18%) had very good results, 55 patients (45.1%) had good results, 26 patients (21.3%) had moderate results, and 11 patients (9%) had poor results. We achieved a success rate of 69.7% (n:85) with excellent, very good, and good results.

Infection was observed in 20 patients (16.4%), 8 of whom developed it in the early period, while 12 had late-onset infections. Twelve patients recovered with parenteral antibiotic treatment. Six patients were treated with debridement and a single course of parenteral antibiotics. Debridement was performed twice in 2 patients. Among these, vancomycin-resistant enterococci (VRE) were detected in one patient, but the infection did not regress, leading to resection arthroplasty. In the other patient with persistent infection, the PFN was removed, resulting in a cure.

Implant failure occurred in 22 patients (18%). Of these, 6 had a Z effect, 4 had a reverse Z effect, and 12 had cut-out implants. Loose screws were removed from 8 patients, PFNs were removed and replaced with a partial prosthesis in 5 patients, and revision with PFNs was performed in 9 patients. Femoral shaft fractures distal to PFNs occurred in 3 patients (2.4%). Osteosynthesis with a long femoral intramedullary nail was performed in 1 patient on the 4th postoperative day, while osteosynthesis with a plate screw was performed in 2 patients during the 2nd and 4th postoperative months. Nonunion was observed in 2 cases (1.6%), both of which were subsequently treated with revision hemiarthroplasty.

One patient with pulmonary embolism on the 2nd postoperative day was transferred to the intensive care unit and later to an inpatient clinic after stabilization, followed by discharge with 2×0.6 enoxaparin sodium treatment. On postoperative day 3, 1 patient was diagnosed with deep vein thrombosis and was treated with antiembolism stockings and 2×0.6 enoxaparin sodium. At the 13th postoperative month, 1 patient developed avascular necrosis of the femoral head; thus, the PFN was removed, and total hip arthroplasty was performed. Decubitus ulcers developed in the sacral and gluteal regions in 9 patients and in the calcaneal region in 1 patient. These ulcers were treated with dressings without requiring additional surgery.

Analyzing implant failure and fracture types, the highest implant failure rate was observed in Modified Evans-Jensen type 5 fractures (11 out of 30 patients, 36.7%), though the difference was not statistically significant ($p>0.05$). There was no correlation between implant failure and ASA classification, age, gender, causes of trauma, or Harris Hip Score ($p>0.05$).

Infection developed in 8 out of 30 patients (26.7%) with type 5 fractures and was significantly more common in type 5 fractures ($p<0.05$). Infection showed no statistical correlation with ASA classification, age, gender, causes of trauma, or Harris Hip Score ($p>0.05$). There was no significant relationship between infection and implant failure ($p>0.05$).

The Harris Hip Score of patients classified as ASA-1 was significantly higher ($p<0.05$). Additionally, the Harris Hip Score of patients whose trauma was caused by falling from a height was significantly lower ($p<0.05$).

Discussion

With advancements in the treatment of chronic diseases and improved living conditions, individual life expectancy has increased. The decrease in bone quality with aging increases the incidence of hip fractures, particularly intertrochanteric fractures. These patients, who often have additional systemic disorders, may experience complications such as deep vein thrombosis, pulmonary

embolism, pneumonia, uremia, urinary tract infections, and pressure ulcers, which negatively impact prognosis and increase mortality due to prolonged hospitalization after the fracture. Therefore, the primary goal of treatment is to provide stable fixation and enable early mobilization[10-14].

In balanced intertrochanteric femur fractures, where the medial support region remains intact, the load borne by the implant is reduced. Treatment options for unstable fractures, however, remain controversial. Biomechanical studies have demonstrated that intramedullary (IM) nails provide a more favorable load distribution over the femoral calcar through the medialization effect, making them a more suitable technique compared to extramedullary implants[14-16]. IM nails decrease the likelihood of implant failure by reducing the tension forces on the nail due to their shorter load arm compared to extramedullary systems[17]. Although the failure rate associated with dynamic hip screws (DHS) in balanced fractures is <5%, this rate increases to 20% in unstable fractures. Sadowski et al.[18] examined 85 patients with AO type 3 fractures and found that while failure occurred in only one case in the PFN group (20 cases), implant failure or nonunion was observed in 7 of 19 patients treated with dynamic condylar screws. Simmermacher et al.[16] reported that complications associated with PFN usage were predominantly seen in AO type 2 fractures. Domingo et al.[19] found that among 295 cases requiring secondary surgery, 10 had AO type 2 or 3 fractures. In our study, most complications were observed in unbalanced fractures, particularly Modified Evans-Jensen type 5 fractures.

Various complications related to PFN usage have been reported both intraoperatively and postoperatively, including fractures of the greater trochanter, improper placement of proximal screws, difficulties with distal locking, poor or inadequate reduction, screw stripping, Z effect, reverse Z effect, calcification at the tip of the greater trochanter, heterotopic calcification, femoral neck shortening, nonunion, malunion, cortical thickening in the distal locking region, nail fractures, and femoral diaphysis fractures distal to the nail[15,18,20,21]. The failure to place the hip screw in the correct position or at an appropriate length is a major factor contributing to stripping in PFNs. When a small hip screw is inserted, a "knife effect" occurs with loading. Consequently, the hip screw moves along with the femoral neck screw within the cancellous bone, leading to varus displacement and stripping[22].

Several studies have reported varying rates of stripping. Tyllianakis et al.[23] reported stripping in 1 of 46 patients, Simmermacher et al.[16] in 1 of 191 cases, Domingo et al.[19] in 1 of 295 cases, Al-yassari et al.[24] in 4 of 76 cases, Boldin et al.[21] in 2 of 55 cases, and Schipper et al.[22] in 11 of 211 cases. The Z effect, a complication specific to PFN, is defined as the hip screw migrating into the joint during postoperative weight-bearing[21]. In 1999, modifications to nail design introduced a stop-like feature on the hip screw to prevent its migration into the joint. The reverse Z effect refers to the lateral displacement of the anti-rotation screw[23]. Papasimos et al.[25] reported the Z effect in 4 cases and the reverse Z effect in 1 case, Tyllianakis et al.[23] observed the Z effect in 5 cases and the reverse Z effect in 1 case, while Boldin et al.[21] reported the Z effect in 3 cases and the reverse Z effect in 2 cases.

In our study, implant failure was observed in 22 patients (18%). Among these, 6 exhibited the Z effect, 4 had the reverse Z effect, and 12 experienced cut-out. Loose screws were removed in 8 patients, PFNs were removed and replaced with partial prostheses in 5 patients, and revision with PFNs was performed in 9 patients. The highest rate of implant failure was observed in Modified Evans-Jensen type 5 fractures (11 out of 30 patients, 36.7%), although the difference was not statistically significant ($p>0.05$). No significant correlation was found between implant failure and ASA classification, age, gender, causes of trauma, or Harris Hip Score ($p>0.05$).

For cut-out, the placement of proximal screws, the quality of reduction, and the tip-apex distance are crucial factors[26]. Baumgaertner et al.[27] emphasized that the tip-apex distance is an important surgical marker in intertrochanteric fracture surgery and plays a key role in determining the location of the lag screw. Lopez-Cautinho et al.[28] highlighted the significance of the calcar tip-apex distance, a new measurement for lag screw placement. According to their study, the ideal placement of the screw is center-center, but if there is a deviation, center-inferior placement is preferable to reduce the risk of cut-out. In our opinion, ensuring that the lag screw is positioned centrally on both anteroposterior and lateral radiographs is essential for preventing cut-out.

Postoperative infection in intertrochanteric fractures has been reported at rates ranging from 0.15% to 15%. Studies with the lowest infection rates employed perioperative antibiotic prophylaxis[29]. Infections are generally classified as superficial or deep. Superficial infections typically present in the early postoperative period with wound redness, localized warmth, and fever. These infections should be managed with appropriate antibiotic therapy, debridement

when necessary, open drainage, and secondary wound healing. If a deep infection is suspected, early intervention is critical to prevent the development of a chronic low-grade infection, which can lead to complications such as nonunion or osteomyelitis. Deep infections may manifest before or after fracture healing or even years after surgery and are associated with high morbidity. Symptoms include unexplained hip pain, decreased range of motion, and an elevated erythrocyte sedimentation rate, while leukocytosis and fever are usually absent. Treatment involves surgical debridement and antibiotic therapy. If fracture healing is insufficient, implant removal should be avoided. However, if the hip joint is involved, implant removal and excisional arthroplasty may be necessary[30].

In our study, infection was observed in 20 patients (16.4%), with 8 occurring in the early postoperative period and 12 in the late period. Infection developed in 8 of 30 patients (26.7%) with type 5 fractures, making it significantly more common in this fracture type. However, infection showed no statistical correlation with ASA classification, age, gender, causes of trauma, or Harris Hip Score ($p>0.05$).

Nonunion of trochanteric fractures occurs in 1%-2% of cases and is typically seen in fractures lacking continuity in the medial calcar region. Most cases of nonunion are associated with implant failure and screw perforation into the femoral head within the first year[31]. In our study, nonunion was observed in 2 patients (1.6%), both of whom were revised with a partial prosthesis.

Avascular necrosis of the femoral head is a very rare complication of intertrochanteric fractures, and its pathophysiology remains poorly understood. Baixauli et al.[32] reported an avascular necrosis rate of 0.55% in their case series. In our study, avascular necrosis was observed in 1 patient (0.8%) in the femoral head, necessitating total hip arthroplasty after PFN removal.

Conclusion

Our complication rates are consistent with those reported in the literature. Most of the complications occurred in unbalanced fractures (Modified Evans-Jensen type 5, AO/OTA 31A2.3) and were primarily related to issues with fixation and reduction of the proximal fragment. Therefore, applying the nail according to the proper technique with acceptable reduction is crucial to achieving balanced osteosynthesis in such fractures.

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References

1. Larsson S. Treatment of osteoporotic fractures. Scand J Surg 2002;91:140–6. [CrossRef]
2. Vossinakis IC, Badras LS. The external fixator compared with the sliding hip screw for pertrochanteric fractures of the femur. J Bone Joint Surg Br 2002;84:23–9. [CrossRef]
3. Koval KJ, Chen AL, Aharonoff GB, Egol KA, Zuckerman JD. Clinical pathway for hip fractures in the elderly: The Hospital for Joint Diseases experience. Clin Orthop Relat Res 2004:72–81. [CrossRef]
4. Koval KJ, Zuckerman JD. Intertrochanteric fractures. In: Bucholz RW, Heckman JD, editors. Fractures in adults. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2001. p.1635–63.
5. Liporace FA, Egol K, Koval KJ. Operative treatment of intertrochanteric hip fractures: An overview of modern advances and techniques. Oper Techn Orthop 2002;12:83–91.
6. Cummings SR, Nevitt MC. Non-skeletal determinants of fractures: The potential importance of the mechanics of falls. Study of Osteoporotic Fractures Research Group. Osteoporos Int 1994;4:67–70. [CrossRef]
7. Hornby R, Evans JG, Vardon V. Operative or conservative treatment for trochanteric fractures of the femur. A randomised epidemiological trial in elderly patients. J Bone Joint Surg Br 1989;71:619–23. [CrossRef]
8. Siegmeth AW, Gurusamy K, Parker MJ. Delay to surgery prolongs hospital stay in patients with fractures of the proximal femur. J Bone Joint Surg Br 2005;87:1123–6. [CrossRef]
9. Schmitz PP, Hannink G, Reijmer J, Somford MP, Van Susante JLC. Increased failure rates after the introduction of the TFNA proximal femoral nail for trochanteric fractures: Implant

related or learning curve effect? Acta Orthop 2022;93:234–40.
10. Haslhofer DJ, Stiftinger JM, Kraml N, Dannbauer F, Schmolmüller C, Gotterbarm T, et al. Complication rates after proximal femoral nailing: Does level of training matter? J Orthop Traumatol 2023;24:56. [CrossRef]
11. Jensen JS. Classification of trochanteric fractures. Acta Orthop Scand 1980;51:803–10. [CrossRef]
12. Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status - Historical perspectives and modern developments. Anaesthesia 2019;74:373–9. [CrossRef]
13. Fogagnolo F, Kfuri M Jr, Paccola CA. Intramedullary fixation of pertrochanteric hip fractures with the short AO-ASIF proximal femoral nail. Arch Orthop Trauma Surg 2004;124:31–7. [CrossRef]
14. Hay D, Parker MJ. Hip fracture in the immobile patient. J Bone Joint Surg Br 2003;85:1037–9. [CrossRef]
15. Madsen JE, Naess L, Aune AK, Alho A, Ekeland A, Strømsøe K. Dynamic hip screw with trochanteric stabilizing plate in the treatment of unstable proximal femoral fractures: A comparative study with the gamma nail and compression hip screw. J Orthop Trauma 1998;12:241–8. [CrossRef]
16. Simmermacher RK, Bosch AM, Van der Werken C. The AO/ASIF-proximal femoral nail (PFN): A new device for the treatment of unstable proximal femoral fractures. Injury 1999;30:327–32.
17. Banan H, Al-Sabti A, Jimulia T, Hart AJ. The treatment of unstable, extracapsular hip fractures with the AO/ASIF proximal femoral nail (PFN)--Our first 60 cases. Injury 2002;33:401–5. [CrossRef]
18. Sadowski C, Lübbeke A, Saudan M, Riand N, Stern R, Hoffmeyer P. Treatment of reverse oblique and transverse intertrochanteric fractures with use of an intramedullary nail or a 95 degrees screw-plate: A prospective, randomized study. J Bone Joint Surg Am 2002;84:372–81. [CrossRef]
19. Domingo LJ, Cecilia D, Herrera A, Resines C. Trochanteric fractures treated with a proximal femoral nail. Int Orthop 2001;25(5):298–301. [CrossRef]
20. Saudan M, Lübbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P. Pertrochanteric fractures: Is there an advantage to an intramedullary nail?: A randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. J Orthop Trauma 2002;16(6):386–93. [CrossRef]
21. Boldin C, Seibert FJ, Fankhauser F, Peicha G, Grechenig W, Szyszkowitz R. The proximal femoral nail (PFN)--A minimal invasive treatment of unstable proximal femoral fractures: A prospective study of 55 patients with a follow-up of 15 months. Acta Orthop Scand 2003;74:53–8. [CrossRef]
22. Schipper IB, Bresina S, Wahl D, Linke B, Van Vugt AB, Schneider E. Biomechanical evaluation of the proximal femoral nail. Clin Orthop Relat Res 2002:277–86. [CrossRef]
23. Tyllianakis M, Panagopoulos A, Papadopoulos A, Papasimos S, Mousafiris K. Treatment of extracapsular hip fractures with the proximal femoral nail (PFN): Long term results in 45 patients. Acta Orthop Belg 2004;70:444–54.
24. Al-yassari G, Langstaff RJ, Jones JW, Al-Lami M. The AO/ASIF proximal femoral nail (PFN) for the treatment of unstable trochanteric femoral fracture. Injury 2002;33:395–9. [CrossRef]
25. Papasimos S, Koutsojannis CM, Panagopoulos A, Megas P, Lambiris E. A randomised comparison of AMBI, TGN and PFN for treatment of unstable trochanteric fractures. Arch Orthop Trauma Surg 2005;125:462–8. [CrossRef]
26. Şişman A, Avci Ö, Çepni SK, Batar S, Polat Ö. Risk factors for cut-out in intertrochanteric fractures treated with proximal femoral nail of double proximal screw design. J Clin Orthop Trauma 2022;28:101832. [CrossRef]
27. Baumgaertner MR, Solberg BD. Awareness of tip-apex distance reduces failure of fixation of trochanteric fractures of the hip. J Bone Joint Surg Br 1997;79:969–71. [CrossRef]
28. Lopes-Coutinho L, Dias-Carvalho A, Esteves N, Sousa R. Traditional distance "tip-apex" vs. new calcar referenced "tip-apex" - Which one is the best peritrochanteric osteosynthesis failure predictor? Injury 2020;51:674–7. [CrossRef]
29. Zuckerman JD, Skovron ML, Koval KJ, Aharonoff G, Frankel VH. Postoperative complications and mortality associated with operative delay in older patients who have a fracture of the hip. J Bone Joint Surg Am 1995;77:1551–6. [CrossRef]
30. Windolf J, Hollander DA, Hakimi M, Linhart W. Pitfalls and complications in the use of the proximal femoral nail. Langenbecks Arch Surg 2005;390:59–65. [CrossRef]
31. Mariani EM, Rand JA. Nonunion of intertrochanteric fractures of the femur following open reduction and internal fixation. Results of second attempts to gain union. Clin Orthop Relat Res 1987:81–9. [CrossRef]
32. Baixauli F, Vicent V, Baixauli E, Serra V, Sánchez-Alepuz E, Gómez V, et al. A reinforced rigid fixation device for unstable intertrochanteric fractures. Clin Orthop Relat Res 1999:205–15. [CrossRef]