ORIGINAL ARTICLE

# Factors influencing mechanical failure following intramedullary nailing of proximal femur fractures: a retrospective cohort study

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## ABSTRACT

**BACKGROUND:** Proximal femur fractures are a common injury in elderly patients and are associated with high morbidity and mortality worldwide. Recent data indicate that the age-standardized incidence of hip fractures in adults over 55 years has increased significantly. We aimed to identify radiographic stability parameters and patient- or procedure-related factors associated with clinical fixation success following intramedullary nailing of proximal femur fractures.

**METHODS:** In this retrospective study, we evaluated 373 patients aged ≥35 years who underwent proximal femoral nail (PFN) implantation for intertrochanteric, pertrochanteric, subtrochanteric, or reverse-oblique femur fractures at our tertiary center between 2012 and 2024. Fractures were classified preoperatively using the Evans classification system, and the quality of reduction was graded as good, fair, or poor according to the standard radiographic Modified Baumgaertner criteria. Radiographic variables, including proximal lag screw tip-head distance (ApLAG1), distal lag screw tip-head distance (ApLAG2), ApLAG2-calcar distance, lesser trochanter-calcar distance, lateral lag screw tip-apex distance (LatTAD), and normal-side lesser trochanter-calcar distance, were measured postoperatively. Clinical outcomes were categorized into two groups: success or failure.

**RESULTS:** The cohort (mean age: 78.06±12.79 years; 66.5% female) included 262 (70.2%) standard PFNs, 79 (21.2%) integrated intertrochanteric antegrade nails (InterTAN) PFNs, and 32 (8.6%) single-screw PFNs. Overall, 359 patients (96.2%) had successful fixation and 14 (3.8%) experienced failure. No significant differences were found in radiographic parameters between the success and failure groups. PFN type did not influence radiographic measurements except for ApLAG2-related variables, in which InterTAN and single-screw nails differed from standard PFNs ($p<0.001$). Univariate analysis revealed that only poor reduction quality was significantly associated with failure ($\chi^2=36.298$; $p<0.001$).

**CONCLUSION:** Quality of fracture reduction emerged as the sole independent predictor of PFN fixation success, whereas patient demographics, Evans classification, and implant design did not significantly affect outcomes. Surgeons should prioritize achieving near-anatomic alignment and stable implant positioning to minimize mechanical failure.

**Keywords:** Proximal femur fractures; proximal femoral nail; radiological assessment; reduction quality.

## INTRODUCTION

Proximal femur fractures are one of the most commonly encountered injuries in elderly patients and are associated with high rates of morbidity and mortality worldwide.[1] These injuries particularly affect individuals aged 55 years and older, with incidence rates ranging from 434 to 616 per 100,000 population depending on the region.[2,3] Moreover, previous

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studies have revealed that the global age standardized incidence rate of hip fractures in adults aged ≥55 years increased from 781.56 per 100,000 in 1990 to 948.81 per 100,000 in 2021, reflecting an increasing burden on healthcare systems due to population aging.[4] Most proximal femur fractures in this demographic result from low energy, ground level falls, underscoring the interplay between osteoporosis, frailty, and fall risk.[5] The global burden of hip fractures is projected to nearly double by 2050 due to population aging, exacerbating the socioeconomic strain on health systems and emphasizing the need for optimal surgical strategies.[6,7]

The AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/ Orthopaedic Trauma Association) classification system categorizes proximal femur fractures into femoral neck (31B), intertrochanteric (31A), and subtrochanteric (32) patterns, offering a standardized framework to guide surgical planning.[8] Within intertrochanteric fractures, simple two part patterns (31A1) are considered stable, whereas comminuted or reverse oblique configurations (31A2–31A3) pose biomechanical challenges that require more robust fixation constructs.[8] Extramedullary devices such as dynamic hip screws have been widely used; however, intramedullary nails, by virtue of their load-sharing design, shorter lever arm, and minimally invasive insertion, offer superior biomechanical stability, particularly in unstable fracture patterns.[9-11] Randomized clinical trials have demonstrated comparable one year functional outcomes between intramedullary nailing and sliding hip screws, with intramedullary nails showing advantages in maintaining reduction and enabling earlier weight bearing.[12]

Postoperative radiographic parameters such as tip apex distance (TAD), restoration of the neck shaft angle, and calcar support serve as quantitative measures of implant positioning and mechanical stability.[13,14] A TAD exceeding 25 mm is reported to be strongly associated with an increased risk of lag screw cut out, emphasizing the importance of precise implant placement.[14] Cephalomedullary nailing in unstable intertrochanteric fractures yields union rates of 85–93% at three to six months postoperatively, with most patients achieving full or near full weight bearing by three months.[15,16] Despite these favorable union rates, mechanical complications such as screw cut out and peri implant fractures occur in up to 10% of cases, indicating the need for meticulous reduction techniques and appropriate implant selection.[17]

In accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies, we aimed to identify stability parameters and patient or procedure related factors associated with optimal fixation and early functional recovery by conducting a retrospective cohort analysis of patients treated with intramedullary nailing for proximal intertrochanteric, pertrochanteric, subtrochanteric, and reverse oblique femur fractures.

## MATERIALS AND METHODS

### Study Design and Patient Selection

This retrospective cohort study was conducted in accordance with the STROBE guidelines. Ethics approval was obtained from the Marmara University Faculty of Medicine Local Clinical Research Ethics Committee (Approval No: 09.2024.998; Date: 2024). Written informed consent was obtained from each patient or their relatives prior to surgery. All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

We reviewed the medical records of all patients aged ≥35 years who sustained a proximal femur fracture (intertrochanteric, pertrochanteric, subtrochanteric, or reverse-oblique patterns) and underwent proximal femoral nail (PFN) implantation at our institution between 2012 and 2024. Patients with a follow-up period of <6 months, incomplete medical records, or a previous surgical history at the operated site were excluded from the study.

Additionally, our inclusion criteria encompassed various proximal femoral fracture types (intertrochanteric, pertrochanteric, subtrochanteric, and reverse-oblique). While this broad inclusion provides a real-world representation of fracture patterns encountered in daily orthopedic practice, it may also introduce heterogeneity in biomechanical behavior and outcomes. Future studies focusing on more homogeneous fracture subtypes may better delineate type-specific mechanical risk factors.

### Data Collection and Baseline Variables

Demographic and clinical data, including age, sex, and fracture side, were obtained from hospital archives. All proximal femur fractures were initially classified on preoperative radiographs according to the Evans classification system. After surgery, reduction quality was classified as good, fair, or poor according to the Modified Baumgaertner criteria.

### Surgical Technique and Postoperative Management

All patients were operated on in the supine position on the fracture table under fluoroscopic guidance. After achieving preoperative reduction on the fracture table, a suitable incision was made. An appropriately sized intramedullary nail was inserted through the apex of the greater trochanter. Proximal and distal locking screws of appropriate size were then placed using a guide system.

### Radiological Assessments

For standard and integrated intertrochanteric antegrade nail (InterTAN)-type PFN measurements, the distances of the proximal locking screws to the femoral head were measured in millimeters, including the anteroposterior proximal lag screw tip–head distance (ApLAG1) and the anteroposterior distal lag screw tip–head distance (ApLAG2). The distance between the lesser trochanter and the calcar was measured on both the fractured and the normal sides. The distance between the distal proximal locking screw and the calcar was also measured (ApLAG2–calcar distance). Additionally, the distance from the lag screw to the apex of the femoral head was measured on the lateral plane, defined as the lateral tip–apex distance (LatTAD) (Figs. 1, 2).

For single-screw PFN measurements, the distance of the proximal locking screw to the femoral head was measured in millimeters (ApLAG1). The distance between the lesser trochanter and the calcar was measured on both the fractured and normal sides. The distance from the proximal locking screw to the calcar was also measured and was given the same designation to allow comparison with other PFN systems (ApLAG2–calcar distance). The distance from the lag screw to the apex of the femoral head was measured on the lateral plane (LatTAD) (Fig. 3).

### Data Analysis

Continuous variables were expressed as mean±standard deviation (SD). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Comparisons among three groups were performed using one-way analysis of variance (ANOVA), followed by Tukey's honestly significant

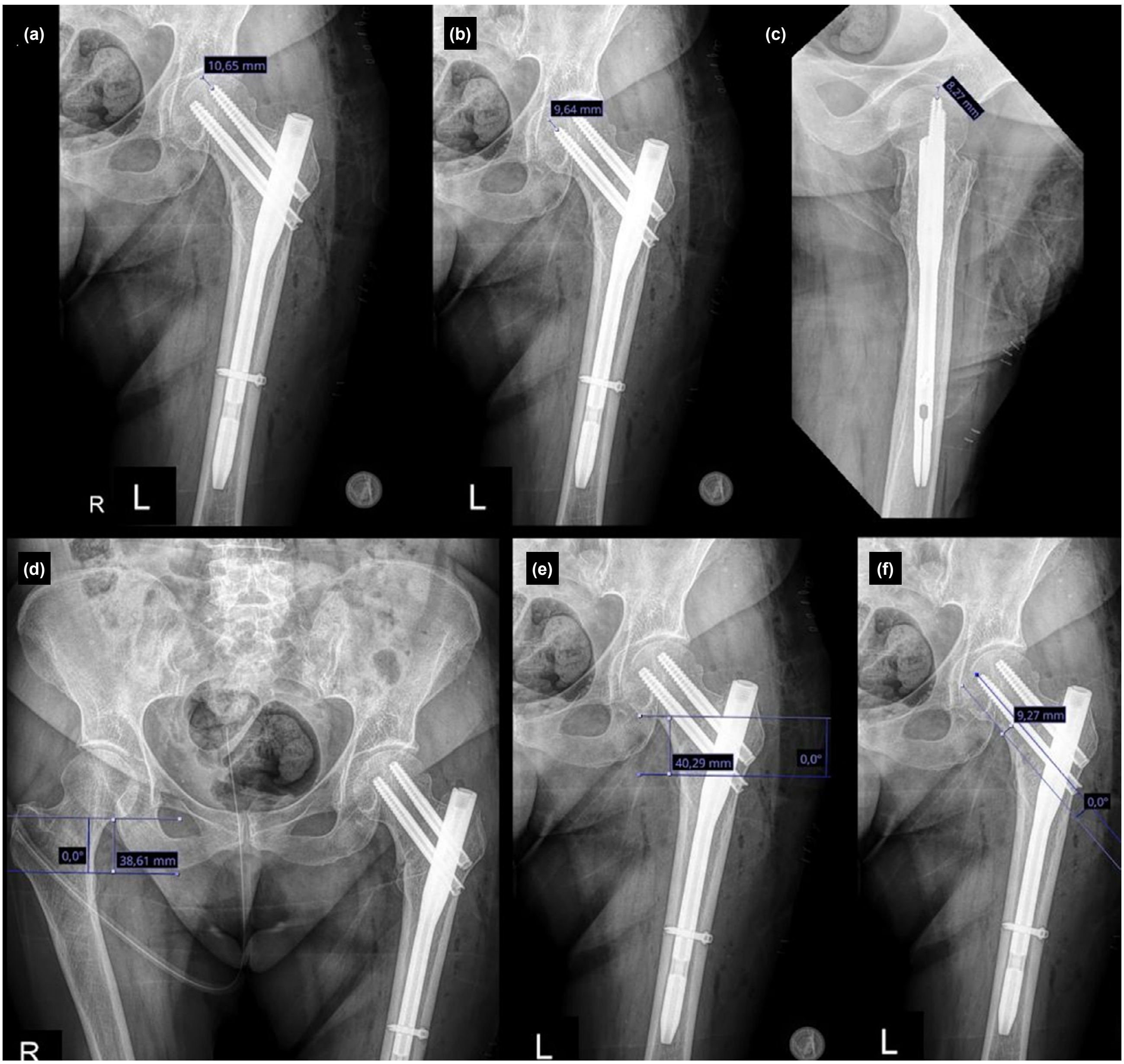


**Figure 1.** Radiographic measurements for the standard proximal femoral nail (PFN). **(a)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(b)** Anteroposterior distal lag screw tip–head distance (ApLAG2); **(c)** Lateral tip–apex distance (LatTAD); **(d)** Normal-side trochanter minor-calcar distance; **(e)** Trochanter minor-calcar distance; **(f)** ApLAG2–calcar distance.

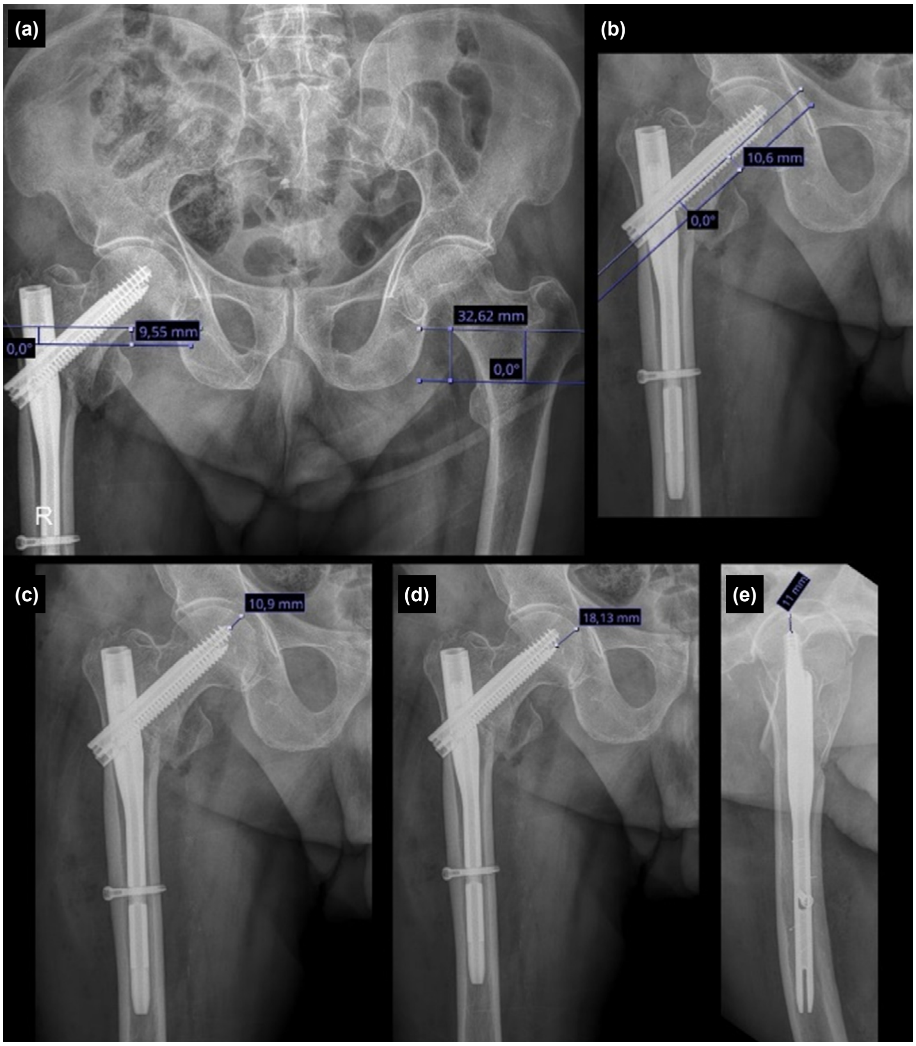


**Figure 2.** Radiographic measurements for the integrated intertrochanteric antegrade nail (InterTAN) type proximal femoral nail (PFN). **(a)** Trochanter minor-calcar distance and normal-side trochanter minor-calcar distance; **(b)** Anteroposterior distal lag screw–calcar distance (ApLAG2–calcar distance); **(c)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(d)** ApLAG2; **(e)** Lateral tip–apex distance (LatTAD).

difference (HSD) test. Comparisons between two groups were conducted using Student's t-test. Categorical variables were presented as frequencies and percentages, and comparisons were performed using the chi-square test. All hypothesis tests were two-tailed, and a p-value <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA).

## RESULTS

A total of 373 patients with complete data were included in the analysis. The mean age of the cohort was 78.06±12.79 years. Seventy-nine patients (21.2%) received an InterTAN PFN, 32 (8.6%) received a single-screw PFN, and 262 (70.2%) received a standard PFN. Of the fractures, 187 (50.1%) occurred on the right side and 186 (49.9%) on the left. According to the Evans classification, the most common fracture types were type 5 (98, 26.3%) and type 4 (92, 24.7%), whereas type R comprised nine cases (2.4%). Reduction quality was rated as "good" in 175 patients (46.9%), "moderate" in 142 (38.1%), and "poor" in 56 (15.0%). Overall, 359 patients (96.2%) had a successful clinical outcome, while 14 (3.8%) experienced failure (Table 1).

Among the continuous radiographic parameters, no significant differences were observed between patients with successful versus failed outcomes (ApLAG1, p=0.186; ApLAG2, p=0.205; ApLAG2–calcar distance, p=0.946; trochanter minor–calcar distance, p=0.632; lateral lag screw-apex distance, p=0.061; normal-side fragment–calcar distance, p=0.750) (Table 2).

Comparisons across PFN types revealed that ApLAG1 did not differ significantly (p= 0.988), whereas ApLAG2 (p<0.001), ApLAG2–calcar distance (p<0.001), trochanter minor–calcar

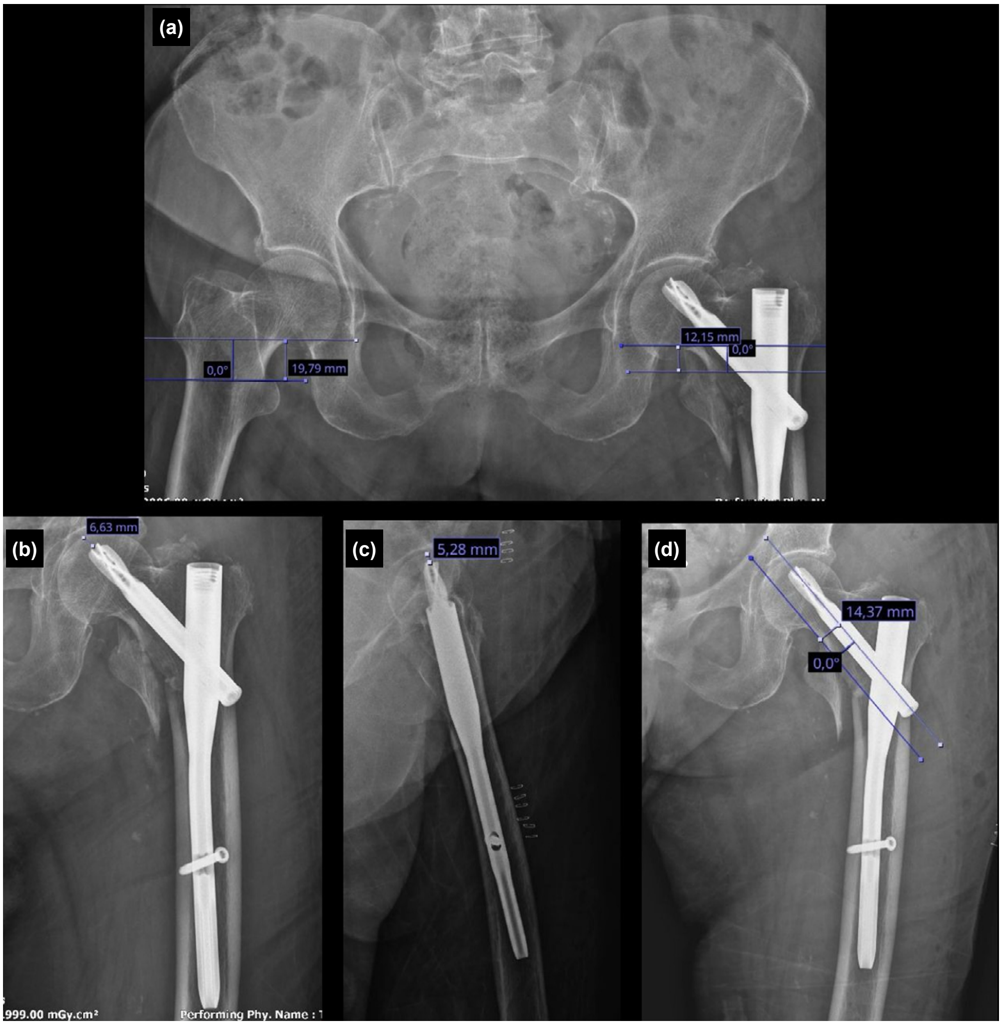


**Figure 3.** Radiographic measurements for the single-screw type proximal femoral nail (PFN) radiographic measurements. **(a)** Trochanter minor-calcar distance and normal-side trochanter minor-calcar distance; **(b)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(c)** Lateral tip–apex distance (LatTAD); **(d)** Anteroposterior distal lag screw–calcar distance (ApLAG2–calcar distance).

distance (p=0.046), lateral lag screw-apex distance (p=0.023), and normal-side fragment–calcar distance (p=0.040) all varied significantly by implant type (Table 3). Post hoc analyses indicated that InterTAN PFNs had greater initial ApLAG2 angulation values and ApLAG2–calcar distances than standard PFNs, and that single-screw PFNs differed significantly from both other groups in terms of ApLAG2 measurements.

As summarized in Table 4, univariate analyses were performed to assess the association between several demographic, fracture-related, and implant-related factors and clinical outcome (success versus failure). Age was compared between groups using an independent t-test and showed no significant difference. Similarly, sex, fracture laterality (right versus left), and PFN type (standard, InterTAN, single-screw) showed no statistically significant relationship with clinical failure. Evans classification (types 1–R) was also not associated with outcome (Table 4). By contrast, reduction quality demonstrated a highly significant association with clinical outcome, indicating that cases rated as "poor" reduction were more likely to experience failure than those with "moderate" or "good" reduction. No other factor reached statistical significance. Collectively, these results indicate that, among the variables tested, only inadequate fracture reduction was predictive of postoperative failure (Table 4).

## DISCUSSION

In this cohort of patients undergoing intramedullary nailing for proximal femur fractures, we found that reduction quality was the sole independent predictor of mechanical failure, whereas age, sex, fracture laterality, nail design (standard PFN, InterTAN, single-screw PFN), and Evans classification were not significant predictors. Multivariate analysis showed that inadequate reduction (malalignment or loss of cortical support) conferred a substantially higher odds of fixation failure (e.g. cut-out, implant breakage, or nonunion requiring revision), while the confidence intervals for other factors all

**Table 1.** Patient characteristics

| Characteristic | N (%)/Mean±SD |
|---|---|
| Age (years) | 78.06±12.79 |
| Sex | |
| Male | 125 (33.5) |
| Female | 248 (66.5) |
| Fracture side | |
| Right | 187 (50.1) |
| Left | 186 (49.9) |
| Evans classification | |
| Type 1 | 24 (6.4) |
| Type 2 | 69 (18.5) |
| Type 3 | 81 (21.7) |
| Type 4 | 92 (24.7) |
| Type 5 | 98 (26.3) |
| Type R | 9 (2.4) |
| Reduction quality | |
| Poor | 56 (15.0) |
| Moderate | 142 (38.1) |
| Good | 175 (46.9) |
| PFN type | |
| Standard PFN | 262 (70.2) |
| InterTAN PFN | 79 (21.2) |
| Single-screw PFN | 32 (8.6) |
| Clinical outcome | |
| Success | 359 (96.2) |
| Failure | 14 (3.8) |

PFN: Proximal femoral nail.

crossed unity (p>0.05). This finding underscores that surgical technique and alignment are the dominant determinants of clinical outcomes in these cases. Cho et al.[18] reported that "poor reduction (type P)" on the lateral view was associated with a very high risk of failure (odds ratio [OR]=12.7) in geriatric trochanteric nail fixation. Similarly, recent studies emphasize that the quality of reduction is the most crucial controllable predictor of improved outcomes, as well as survival, in proximal femoral fractures.[19-21]

By contrast, patient demographics and fracture classification showed no apparent influence on failure in our cohort. We observed no significant difference in failure rates according to age or sex. This suggests that, once surgical stabilization is achieved, biological factors such as bone quality (which correlates with age and sex) may play a lesser role than the mechanical environment. Some prior studies have reported nominal associations between poor bone quality or comminution and fixation failure; however, our data did not support a clear effect of these unmodifiable factors. Similarly, we found no difference between right- and left-sided fractures. Regarding fracture type, the Evans classification did not predict failure, suggesting that the traditional Evans system may be relatively coarse. Interestingly, Donadono et al.[22] also reported that fracture pattern (AO type A1/A2/A3) did not independently affect cut-out risk when reduction quality was controlled, whereas Cho et al.[18] identified AO 31-A3 (reverse-oblique) fractures as a risk factor. However, our sample may have included too few of these cases to demonstrate significance under the Evans classification scheme. Overall, the lack of association with Evans type in our study suggests that surgeons should focus more on reduction quality than on nominal fracture classification when predicting implant success.

In our study, we did not observe any significant differences in failure rates among PFN constructs (standard PFN vs. InterTAN vs. single-screw PFN). In other words, nail design did not influence failure rates. Although our findings suggest that nail design did not significantly affect failure rates, this conclusion should be interpreted with caution. Differences in fracture morphology, surgeon experience, and implant familiarity may obscure subtle design-related effects. Furthermore, biomechanical and clinical studies have demonstrated that dual-screw systems such as the InterTAN provide superior rotational stability and resistance to varus collapse,

**Table 2.** Comparison of radiographic parameters according to clinical outcome

| | Success (n=359) | Failure (n=14) | p value |
|---|---|---|---|
| ApLAG1 (mm) | 9.65±3.48 | 10.97±4.89 | 0.186 |
| ApLAG2 (mm) | 13.04±4.77 | 14.83±5.79 | 0.205 |
| ApLAG2–calcar distance (mm) | 8.64±5.41 | 8.74±5.15 | 0.946 |
| Trochanter minor–calcar distance (mm) | 21.76±10.62 | 23.20±11.62 | 0.632 |
| LatTAD (mm) | 8.75±3.58 | 10.70±6.08 | 0.061 |
| Normal-side trochanter minor–calcar distance (mm) | 27.38±6.83 | 26.73±8.90 | 0.750 |

ApLAG1: Anteroposterior proximal lag screw tip-head distance; ApLAG2: Anteroposterior distal lag screw tip-head distance.

**Table 3.** Radiographic parameters according to proximal femoral nail (PFN) type

| | Standard PFN (n=262) | InterTAN PFN (n=79) | Single PFN (n=32) | p-value |
|---|---|---|---|---|
| ApLAG1 (mm) | 9.65±3.47 | 9.69±3.54 | 9.62±3.64 | 0.988 |
| ApLAG2 (mm) | 12.27±4.25 | 16.18±4.97 | 6.07±10.51 | <0.001 |
| ApLAG2–calcar distance (mm) | 7.50±5.04 | 11.79±5.78 | 10.33±3.45 | <0.001 |
| Trochanter minor–calcar distance (mm) | 22.70±10.82 | 19.56±9.77 | — | 0.046 |
| LatTAD (mm) | 8.48±3.68 | 9.65±3.75 | — | 0.023 |
| Normal-side trochanter minor–calcar distance (mm) | 27.95±7.10 | 25.99±5.90 | — | 0.040 |

ApLAG1: Anteroposterior proximal lag screw tip-head distance; ApLAG2: Anteroposterior distal lag screw tip-head distance; PFN: Proximal femoral nail.

**Table 4.** Association between clinical factors and clinical outcomes

| Factor | Test | Statistic (df) | p-value |
|---|---|---|---|
| Sex | Chi-square | $\chi^2$=0.953 (1) | 0.329 |
| Fracture side | Chi-square | $\chi^2$=0.308 (1) | 0.579 |
| PFN type | Chi-square | $\chi^2$=1.841 (2) | 0.398 |
| Reduction quality | Chi-square | $\chi^2$=36.298 (2) | <0.001 |
| Evans classification | Chi-square | $\chi^2$=3.275 (5) | 0.658 |

PFN: Proximal femoral nail; X: Chi-square.

particularly in unstable or osteoporotic fractures.[23-25] Liao et al.,[25] in a systematic review and meta-analysis, reported that InterTAN nails exhibited lower rates of cut-out, varus collapse, and shaft fracture compared with single-screw PFN systems, highlighting their enhanced mechanical stability. Similarly, Yalın et al.[23] found that InterTAN designs minimized the risk of the Z-effect and maintained reduction more effectively than other intramedullary nails. In another comparative study, Kürüm et al.[24] observed that nail protrusion occurred in 31.6% of single-screw Talon PFNs, whereas no such cases were reported with InterTAN nails, supporting the biomechanical superiority of the dual-screw construct. Including these mechanical and design factors in future analyses could further refine the understanding of implant-specific performance and guide surgical decision-making.

We suggest that, assuming proper surgical technique and adequate fracture reduction, all three implants can provide stable fixation. This finding partly diverges from some recent literature favoring the dual-screw InterTAN design. It has been reported that InterTAN nails yield superior functional scores and avoid the so-called "Z-effect" observed with some single-screw nails.[23] A systematic review, on the other hand, found that PFN antirotation (single-screw) systems had higher rates of shaft fracture, varus collapse, and cut-out than InterTAN nails, and suggested that InterTAN's advantage is attributed to its static, interlocking lag-screw system, which provides greater anti-rotational stability and prevents excessive collapse.[25] In our series, however, these design-related differences may have been mitigated by surgeon preference or the relatively small sample size. It is possible that with optimal reduction and an appropriate TAD, even a single-screw nail can avoid complications. Nonetheless, given the broader evidence, it would be prudent to acknowledge that dual-screw nails may confer greater mechanical robustness, particularly in unstable fracture patterns or osteoporotic bone.[18,23] For example, in a matched comparison of Talon PFN (single-screw) versus InterTAN, no nail protrusions occurred with InterTAN, whereas 31.6% of Talon cases demonstrated protrusion.[24] While our data do not contradict such reports, they suggest that when reduction is optimized, different implant designs can perform comparably in terms of overall failure.

Consistent with other reports, we also found that implant positioning parameters other than reduction quality, such as TAD or screw placement, were not independently associated with failure in multivariate analysis. In our cohort, nearly all nails were inserted with a TAD <25 mm and central screw positioning, reflecting contemporary surgical standards. As a result, TAD did not emerge as a risk factor, whereas studies with greater variability in TAD often identify it as an important predictor of failure. For example, it has been reported that TAD >25 mm significantly predicts cut-out in addition to poor reduction quality.[22] Similarly, a 2025 surgical score analysis (the TSS study) demonstrated that each unit increase in an intraoperative "quality score" (encompassing TAD, screw positioning, cortical support, etc.) markedly reduced the risk of complications, highlighting modifiable factors such as lag screw placement and cortical support (factors closely related to reduction quality and surgical technique) as key drivers of outcome.[26] Our findings, combined with these reports, reinforce that even when an implant is appropriately positioned, the underlying reduction quality and cortical support (particularly medial and anterior) are paramount in preventing failure.[19,22]

As a retrospective analysis, this study is subject to several inherent limitations. First, the study design limits causal inference and may involve missing data or inconsistencies in documentation. Second, the absence of randomization means that unmeasured factors, such as the degree of fracture comminution or bone quality, could have influenced the outcomes. Moreover, the use of the Evans classification may not capture biomechanical instability as comprehensively as the AO/OTA classification system. Another limitation of our study is the relatively short follow-up period (6–12 months). Although this duration is sufficient to capture early mechanical failures such as cut-out or implant breakage, it may not fully reflect late complications such as delayed union or implant fatigue. Future prospective studies with longer follow-up periods are therefore warranted to evaluate long-term functional and radiographic outcomes. In addition, the follow-up period was limited to six to 12 months; therefore, very late failures may have been missed. Lastly, functional or patient-reported outcomes were not collected, as the focus of this study was solely on mechanical fixation success.

Given these limitations, future research should focus on several areas. Prospective, multicenter randomized trials comparing different PFN designs (including InterTAN, single-screw systems, and newer constructs) under standardized surgical protocols could help isolate implant-specific effects. Studies investigating reduction-enhancement strategies, such as 3D fluoroscopy, computer-assisted reduction, or percutaneous cerclage wires, may determine whether these techniques improve alignment and thereby reduce failure rates. Furthermore predictive scoring systems (such as the Trochanteric Surgical Score [TSS], which incorporates reduction quality, tip-apex distance, and bone quality) should be validated across diverse patient populations to guide real-time clinical decision-making. Biomechanical studies are also needed to clarify how small deviations in reduction affect failure risk for different nail designs and to establish clinically acceptable thresholds. Finally, research evaluating bone augmentation techniques—such as cement augmentation or biologic therapies—in patients with poor bone quality may help determine whether these strategies can mitigate failure when optimal reduction cannot be achieved.

## CONCLUSION

In conclusion, our data indicate that the quality of fracture reduction and implant positioning exerts a more critical influence on biomechanical stability and clinical outcomes than the specific choice of intramedullary nail design. Although dual-screw constructs such as the InterTAN nail have demonstrated superior resistance to rotational forces and axial collapse in controlled laboratory studies, these theoretical advantages are realized only when anatomic alignment and cortical support are reestablished intraoperatively. Consequently, surgeons should prioritize restoration of near-anatomic alignment, ensuring medial calcar contact and an appropriate neck-shaft angle, and adhere rigorously to validated radiographic parameters (e.g., Baumgaertner or Chang criteria) at the time of fixation. A key clinical takeaway is that surgeons should devote meticulous attention to fracture reduction intraoperatively, restoring neck-shaft alignment, appropriate abduction, and medial cortical continuity, and potentially employing adjunct techniques such as traction, percutaneous clamps, or open techniques when necessary. Even the most advanced implant cannot compensate for residual malreduction. Future innovations in nail geometry or locking mechanisms should therefore be developed in parallel with surgical techniques that facilitate precise reduction, as the ultimate determinant of implant success remains the mechanical environment created by the surgeon's restoration of fracture anatomy.

Overall, by addressing variability introduced by fracture type, extending follow-up

duration, and exploring implant design differences in greater depth, future research may provide a more comprehensive understanding of factors influencing mechanical failure after intramedullary nailing.

**Ethics Committee Approval:** This study was approved by the Marmara University Faculty of Medicine Local Clinical Research Ethics Committee (Date: 20.09.2024, Decision No: 09.2024.998).

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: M.K.B.; Design: M.K.B., E.K.; Supervision: M.K.B., B.K.; Resource: M.K.B., B.G., A.O.Ç., M.C., E.K., Y.K.A.; Materials: M.K.B., B.G., A.O.Ç., M.C., E.K., Y.K.A.; Data collection and/or processing: M.K.B., B.G., A.O.Ç., M.C., E.K., Y.K.A.; Analysis and/or interpretation: M.K.B., B.G., A.O.Ç., M.C., E.K., Y.K.A.; Literature review: M.K.B., B.G., A.O.Ç., M.C.; Writing: M.K.B., E.K., Y.K.A.; Critical review: M.K.B., B.G.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Proksimal femur kırıklarında intramedüller çivileme sonrası mekanik başarısızlığı etkileyen faktörler: Retrospektif kohort çalışması

AMAÇ: Proksimal femur kırıkları yaşlı hastalarda sık görülen yaralanmalardır ve dünya çapında yüksek morbidite ve mortalite ile ilişkilidir. Güncel veriler, 55 yaş üzeri erişkinlerde yaşa-standardize edilmiş kalça kırığı insidansının anlamlı ölçüde arttığını göstermektedir. Bu çalışmada, proksimal femur kırıklarının intramedüller çivileme sonrası klinik tespit başarısı ile ilişkili radyografik stabilite parametrelerini ve hasta/prosedür kaynaklı faktörleri belirlemeyi amaçladık.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, 2012–2024 yılları arasında üçüncü basamak merkezimizde intertrokanterik, peritrokanterik, subtrokanterik veya ters oblik femur kırığı nedeniyle proksimal femoral çivi (PFN) uygulanan ≥35 yaşındaki 373 hasta değerlendirildi. Kırıklar ameliyat öncesinde Evans sistemi ile sınıflandırıldı ve redüksiyon kalitesi standart radyografik Modifiye Baumgaertner kriterlerine göre iyi, orta veya kötü olarak derecelendirildi. Postoperatif dönemde, proksimal lag vidası uç-baş mesafesi (ApLAG1), distal lag vidası uç-baş mesafesi (ApLAG2), ApLAG2-kalkar mesafesi, küçük trokanter-kalkar mesafesi, lateral lag vidası uç-apeks mesafesi (LatTAD) ve normal taraf küçük trokanter-kalkar mesafesi gibi radyografik değişkenler ölçüldü. Klinik sonuçlar başarı veya başarısızlık olarak iki grupta değerlendirildi.

BULGULAR: Çalışma grubunun ortalama yaşı 78.06±12.79 yıl olup, %66.5'i kadındı. Hastalara 262 (%70.2) standart PFN, 79 (%21.2) InterTAN PFN ve 32 (%8.6) tek vidalı PFN uygulandı. Genel olarak 359 hasta (%96.2) başarılı fiksasyon elde ederken, 14 hastada (%3,8) başarısızlık gözlendi. Başarı ve başarısızlık grupları arasında radyografik parametreler açısından anlamlı fark bulunmadı. PFN tipi, ApLAG2 ile ilişkili değişkenler dışında radyografik ölçümleri etkilemedi; bu parametrelerde InterTAN ve tek vidalı çiviler standart PFN'den farklı bulundu ($p<0.001$). Tek değişkenli analizde yalnızca kötü redüksiyon kalitesinin başarısızlık ile anlamlı ilişkili olduğu saptandı ($\chi^2=36.298$; $p<0.001$).

SONUÇ: Kırık redüksiyon kalitesi, PFN fiksasyon başarısının tek bağımsız belirleyicisi olarak öne çıkmıştır. Buna karşılık, hasta demografisi, Evans sınıflaması ve implant tasarımı sonuçları anlamlı olarak etkilememiştir. Cerrahların mekanik başarısızlık riskini en aza indirmek için olabildiğince anatomik hizalanma ve stabil implant pozisyonu sağlamaya öncelik vermeleri gerekmektedir.

Anahtar sözcükler: Proksimal femur kırıkları; proksimal femoral çivi; radyolojik değerlendirme; redüksiyon kalitesi.

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