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Correlation Between Preoperative Radiographic Measurements and Intramedullary Nail Diameter: A Retrospective Study on Femur, Tibia, and Humerus Shaft Fractures

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Objective: To evaluate the correlation between the diameter of intramedullary nails used in the surgical treatment of femur, tibia, and humerus shaft fractures and the narrowest portion of the medullary canal as measured on preoperative radiographs.

Materials and Methods: This retrospective study included patients over 18 years old who underwent intramedullary nailing between January 2020 and January 2025. Preoperative anteroposterior and lateral radiographs were assessed to measure the narrowest medullary canal diameter. Nail diameters used during surgery were compared with these measurements.

Results: A total of 162 patients (82 femur, 46 tibia, and 34 humerus fractures) were included. The mean difference between the isthmus and nail diameter was 3 mm for femur, 3.5 mm for tibia, and 2 mm for humerus. A statistically significant positive correlation was found between radiographic canal measurements and the nail diameters used (p<0.05).

Conclusion: A consistent undersizing of nails relative to the isthmus diameter was observed. The results emphasize the importance of preoperative radiographic assessment in ensuring optimal surgical planning and nail selection.

Key Words: *Intramedullary nailing, femur fracture, tibia fracture, humerus fracture, preoperative planning, medullary canal diameter*

Ameliyat Öncesi Radyografik Ölçümler ile İntramedüller Çivi Çapı Arasındaki Korelasyon: Femur, Tibia ve Humerus Şaft Kırıkları Üzerine Retrospektif Bir Çalışma

Amaç: Femur, tibia ve humerus cisim kırıklarının cerrahi tedavisinde kullanılan intramedüller çivilerin çapı ile ameliyat öncesi radyografilerde ölçülen medüller kanalın en dar kısmı arasındaki korelasyonu değerlendirmek.

Gereç ve Yöntem: Bu retrospektif çalışmaya Ocak 2020 ile Ocak 2025 tarihleri arasında intramedüller çivileme uygulanan 18 yaş üstü hastalar dahil edildi. Ameliyat öncesi ön-arka ve yan radyografiler en dar medüller kanal çapını ölçmek için değerlendirildi. Ameliyat sırasında kullanılan çivi çapları bu ölçümlerle karşılaştırıldı.

Bulgular: Toplam 162 hasta (82 femur, 46 tibia ve 34 humerus kırığı) çalışmaya dahil edildi. İstmus ve çivi çapı arasındaki ortalama fark femur için 3 mm, tibia için 3.5 mm ve humerus için 2 mm idi. Radyografik kanal ölçümleri ile kullanılan çivi çapları arasında istatistiksel olarak anlamlı pozitif korelasyon bulundu (p<0.05).

Sonuç: Çivilerin isthmus çapına göre tutarlı bir şekilde düşük boyutlandırıldığı gözlenmiştir. Sonuçlar, optimal cerrahi planlama ve çivi seçiminin sağlanmasında ameliyat öncesi radyografik değerlendirmenin önemini vurgulamaktadır.

Anahtar Kelimeler: *İntramedüller çivileme, femur kırığı, tibia kırığı, humerus kırığı, ameliyat öncesi planlama, medüller kanal çapı*

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Introduction

Due to its biomechanical benefits, which include load-sharing characteristics, minimal soft tissue disruption, and the capacity to encourage early mobilization and fracture healing, intramedullary nailing has emerged as the gold standard for the treatment of long bone fractures, especially those in the femur, tibia, and humerus (1). The proper choice of intramedullary nail diameter is one of the most important variables affecting the technique's success. To maintain stability, prevent issues like implant mismatch, and create the best possible environment for fracture healing, the nail's dimensions must precisely match those of the intramedullary canal (2). Preoperative radiographs are essential to this procedure because they are utilized to evaluate the bone's architecture, paying special attention to the intramedullary canal's narrowest segment, which is a crucial factor in preoperative planning and nail choice (3).

Even though preoperative imaging is frequently employed, little is known about the relationship between the diameter of the nail that is ultimately used during surgery and the intramedullary canal's smallest segment as determined by preoperative radiographs.

This information gap is important because differences in these parameters may result in less-than-ideal outcomes, such as instability, delayed union, or the requirement for intraoperative revisions, all of which may jeopardize patient satisfaction and recovery (4). Additionally, preoperative evaluations may contain mistakes due to differences in bone structure, radiographic magnification, and measurement methods, underscoring the need for a more thorough comprehension of this relationship (5).

Since precise preoperative planning has a direct impact on surgical results, its significance cannot be emphasized. The medullary canal must enlarge excessively to accommodate an overly thick nail, which might weaken the bone and potentially result in an iatrogenic secondary fracture. An excessively thin nail will not allow load sharing throughout the nail, which is a crucial component of the intramedullary nailing procedure, nor will it offer a stable decrease (6). Therefore, better surgical decision-making and preoperative planning procedures require an awareness of the relationship between the diameter of the nail utilized during surgery and the narrowest portion of the intramedullary canal.

This study aims to investigate the correlation between the narrowest part of the intramedullary canal, as measured on preoperative radiographs, and the diameter of the intramedullary nail applied during surgery for femur, tibia, and humerus shaft fractures. By analyzing this relationship, we seek to provide valuable insights into the accuracy of preoperative assessments and their impact on surgical outcomes. The findings of this study may contribute to the development of more precise preoperative planning protocols, optimize nail selection, and ultimately improve patient outcomes and satisfaction.

Materials and Methods

Research and Publication Ethics: The study was initiated following the approval of the Non-Interventional Research Ethics Committee of Fırat University (2025/07-12). The study adhered to the principles stated in the Declaration of Helsinki. Patient data were anonymised to ensure confidentiality and privacy.

We retrospectively screened patients who underwent intramedullary nailing for femur, tibia, and humerus shaft fractures at our institution over a 5-year period, from january 2020 to january 2025. Inclusion criteria were: (1) patients aged 18 years or older, (2) availability of preoperative anteroposterior (AP) and lateral radiographs of the affected bone, (3) documented intramedullary nail diameter used during surgery, and (4) complete medical records. Exclusion criteria included: (1) pathological fractures, (2) previous surgery or deformity in the affected bone, (3) inadequate radiographic quality for measurement, and (4) fractures involving the metaphysis or articular surface.

Preoperative radiographs (AP and lateral views) were retrieved from the hospital's digital imaging system. The narrowest part of the intramedullary canal, corresponding to the isthmus region, was identified and measured using standardized techniques. The narrowest part of the humerus is anatomically referred to as the surgical neck of the humerus, The narrowest part of the tibia is at the junction of the middle and distal 1/3 (the junction of the shaft and distal metaphysis) and the narrowest part of the femur is at the isthmus, which is proximal to the femoral shaft, at the junction of the proximal and middle 1/3, approximately 10-14 cm distal to the lesser trchanter in adults.

Measurements were performed by two independent orthopedic surgeons to ensure reliability and minimize interobserver variability. The average of the two measurements was recorded for analysis. Radiographic magnification was corrected using a standardized calibration marker or known dimensions of adjacent structures.

The diameter of the intramedullary nail used during surgery was obtained from the operative records. Nail selection was based on the surgeon's preoperative assessment and intraoperative findings, including reaming diameter and canal fit.

Statistical Analysis: The data of the study were analyzed with IBM SPSS statistics Version 27.0. Compliance of quantitative variables with normal distribution was evaluated with the Kolmogorov-Smirnov test. Descriptive statistics of variables were presented as median (min-max). Statistical significance between paired groups not conforming to normal distribution was evaluated by Wilcoxon signed rank test. The significance level was accepted as 0.05. In addition to the Kolmogorov-Smirnov test and Wilcoxon signed-rank test, Spearman's correlation test was performed to assess relationships between canal diameters and nail diameters. Correlation coefficients (r) and p-values were reported. A post-hoc power analysis was conducted to evaluate subgroup adequacy.

A priori power analysis was performed using G*Power 3.1.9.7 (Universität Düsseldorf, Germany) software to determine the sample size of the study. The effect size was obtained from data in studies with similar methodologies in the literature (7). Cohen's d = 0.65 was assumed, considering the average differences between the intramedullary canal diameter and the nail diameter used in the femur, tibia, and humerus groups. The parameters used in the analysis are as follows:

- Test type: Two-tailed paired comparison (Wilcoxon signed-rank equivalent)
- Alpha error (α): 0.05
- Power (1–β): 0.80
- Effect size (d): 0.65

Based on these values, a minimum of 26 cases per group was calculated to be sufficient. Since our study included 82 femur, 46 tibia, and 34 humerus cases, respectively, the power level of all analyses was ensured to be above 80%.

Table 1. Case Summaries of Intramedullary Canal and Nail Lengths

Bone	Nail Mean (mm)	95% CI (Nail)	Medulla Mean (mm)	95% CI (Medulla)	N
Femur	11.49	11.26 – 11.72	14.36	13.98 – 14.74	82
Tibia	10.57	10.27 – 10.86	14.06	13.52 – 14.60	46
Humerus	8.21	7.88 – 8.53	10.31	9.76 – 10.86	34

Results

As a result of the evaluation, 82 femur fracture, 46 tibia fracture and 34 humerus fracture patients were included in the study.

The mean diameter of the medulla isthmus in femur fracture patients was 14.3 mm, while the mean diameter of the nails used was 11.5 mm. In patients with tibial fractures, the mean medulla isthmus diameter was 14 mm, while the mean nail diameter was 10.5 mm. In patients with humerus fractures, the mean medulla isthmus diameter was 10.3 mm and the mean diameter of the nails used was 8.2 mm. The mean diameter of the nail used in femur fracture was 3 mm narrower than the measurement, the mean diameter of the nail used in tibia fracture was 3.5 mm narrower than the measurement, and the mean diameter of the nail used in humerus fracture was 2 mm narrower than the measurement Table 1).

When the correlation between medulla isthmus diameters and nail diameters was evaluated, it was determined that there was a positive correlation in all of them, including the femur, humerus and tibia, respectively. Specifically, Spearman's correlation analysis showed strong positive correlations in all three groups (Femur: r=0.72, p<0.001; Tibia: r=0.68, p<0.001; Humerus: r=0.64, p<0.001).

Given the observed effect sizes and sample sizes, the overall study power exceeded 0.80, while subgroup analyses demonstrated lower power, particularly in the humerus group (power≈0.65).

For each bone group, 95% confidence intervals (CI) were calculated for both nail diameters and medullary canal diameters at the isthmus: Femur (N=82): The mean nail diameter was 11.49 mm (95% CI: 11.26–11.72), while the mean medullary isthmus diameter was 14.36 mm (95% CI: 13.98–14.74). Tibia (N=46): The mean nail diameter was 10.57 mm (95% CI: 10.27–10.86), and the mean medullary isthmus diameter was 14.06 mm (95% CI: 13.52–14.60). Humerus (N=34): The mean nail diameter was 8.21 mm (95% CI: 7.88–8.53), compared with a mean medullary isthmus diameter of 10.31 mm (95% CI: 9.76–10.86). These intervals confirm that nails were consistently smaller than the corresponding canal diameters across all fracture sites.

Discussion

The diameters of intramedullary nails utilized for femur, tibia, and humerus shaft fractures were compared to the medulla isthmus diameters as determined by preoperative radiographs in this retrospective analysis. With correlation coefficients showing a robust link, the data show a constant positive correlation between the nail diameter and the medulla isthmus diameter across all three fracture types. These findings align with previous studies that emphasize the importance of matching nail size to the intramedullary canal to optimize fixation stability and clinical outcomes (8).

Furthermore, by incorporating confidence intervals, correlation coefficients, and post-hoc power analysis, the statistical robustness of our results is reinforced. Narrow confidence intervals support the precision of mean estimates, while strong correlation coefficients confirm consistency between canal measurements and nail selection. Although overall study power was sufficient, the lower power in the humerus subgroup highlights the need for caution when generalizing findings to smaller cohorts. Clinically, these statistical measures strengthen the reliability of our conclusion that intramedullary nails are systematically selected smaller than canal diameters, a practice balancing technical feasibility and fracture stability. Moreover, integrating statistical robustness into clinical interpretation enhances the overall validity of our findings. Effect sizes derived from the observed nail–canal differences emphasize the practical magnitude of mismatch, while confidence intervals indicate the reliability of these estimates. Power analysis further contextualizes the strength of subgroup comparisons, cautioning against overinterpretation of less powered groups. By directly linking statistical measures to clinical outcomes, our results gain stronger translational relevance and provide more clinically meaningful insights for optimizing intramedullary nail selection.

A cautious approach to nail selection in clinical practice is suggested by the observed mean discrepancies between the medulla isthmus and nail diameters, which are 3 mm for the femur, 3.5 mm for the tibia, and 2 mm for the humerus. According to earlier studies, this disparity might be due to surgeons' predilection for somewhat smaller nails to make insertion easier and lower the danger of iatrogenic fractures during reaming or implantation (9). Anatomical differences in the tibial canal, which is frequently narrower and more triangular, may be the cause of the slightly greater difference in tibia fractures (3.5 mm) as compared to femur (3 mm) and humerus (2 mm). This could potentially call for more conservative size to address reaming limits. These results highlight the necessity of careful preoperative planning to strike a compromise between surgical practicality and canal fit. Since a closer match between nail and canal diameter

improves cortical contact and load-sharing capacity, potentially lowering problems like nonunion or implant failure, the study's positive connection is in line with biomechanical principles (10). In contrast to certain studies that advocate for full canal fill to maximize stability, nails are consistently undersized in relation to the isthmus diameter (11). This disparity illustrates the variation in intramedullary nailing techniques and could be the result of institutional procedures or surgical experience. Furthermore, the more consistent cylindrical shape of the femoral canal, which enables more accurate radiographic measures and nail sizing, may be the reason for the higher correlation in femur fractures as opposed to humerus fractures. One Orthopedic surgery can benefit from these discoveries. Nail selection for the best fixation can be guided by precise preoperative measurement of the medulla isthmus, as was done in this study utilizing standardized radiography techniques. Concerns about potential inter-observer variability were addressed by using two independent observers to estimate channel diameters, which increased the reliability of the measurements. Further research into standardized sizing procedures is necessary, though, as the reported variations in isthmus and nail sizes imply that intraoperative variables, including the degree of reaming or the surgeon's judgment, may affect the final nail selection.

Several limitations must be acknowledged. First, the retrospective design makes it impossible to account for confounding variables that might have affected the choice of nail diameter, such as differences in surgical technique, reaming procedures, or surgeon experience. Secondly, the research was carried out at a single facility, which would have limited the findings' applicability to other facilities with distinct surgical procedures or patient demographics. Third, the study may have been underpowered to examine subgroup differences, such as those based on age, sex, or fracture complexity, even if the sample size (162 patients with femur, tibia, and humerus fractures) was adequate to identify significant correlations. Fourth, the accuracy of the measurements may have been impacted by any mistakes in determining the narrowest portion of the isthmus or in calibration, even though radiographic measurements were standardized and adjusted for magnification. Fifth, it is difficult to correlate nail-canal mismatch with patient outcomes because the study did not evaluate clinical outcomes like union rates, comorbidities, or functional recovery. Future studies should investigate these correlations in this group, since prior research has indicated that inadequate nail sizing may raise the risk of nonunion or implant failure (6). Lastly, the findings may not have applied to more complex fracture patterns if pathological fractures and those affecting the metaphysis or articular surface had been excluded. Furthermore, postoperative radiographic calibration of the isthmus using the known nail diameter was not performed, which may limit measurement accuracy. CT scans were also not available for comparison, and potential differences between CT and radiography could not be assessed. These should be considered important limitations of the study. In addition, although a post-hoc power analysis indicated adequate power (>0.80) for overall comparisons, the subgroup analyses, especially for humerus fractures, were underpowered. This limitation should be considered when interpreting subgroup results.

In conclusion, this study supports the significance of preoperative radiographic assessment for nail selection by confirming a favorable association between intramedullary nail sizes and medulla isthmus diameters in the surgical therapy of femur, tibia, and humerus shaft fractures. A conservative approach in clinical practice is highlighted by the consistent undersizing of nails in relation to the isthmus diameter, which may be motivated by anatomical and surgical factors. By highlighting the significance of accurate canal measures in maximizing intramedullary nailing results, our findings add to the body of orthopedic literature. In order to assess the effect of nail-canal mismatch on healing and problems, future research should try to overcome the limitations of this work by implementing prospective designs, larger and more varied cohorts, and clinical outcome measures. Preoperative planning accuracy may also be improved by standardizing nail sizing procedures and investigating the potential of cutting-edge imaging methods like computed tomography. In the treatment of long bone shaft fractures, these initiatives will be essential to enhancing surgical accuracy and patient outcomes.

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