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Original Article

Orthopaedics Section

Correlation Between Anthropometric Measurements and Intramedullary Nail Length in Patients with Femoral Fracture: A Cross-sectional Study

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ABSTRACT

Introduction: Intramedullary (IM) nailing is the gold standard treatment for femoral shaft fractures. Selecting the optimal IM nail length is crucial for ensuring proper alignment and minimising complications.

Aim: To explore the relationship between anthropometric measurements and appropriate IM nail length in patients with femoral fractures.

Materials and Methods: This cross-sectional study was conducted in 30 patients in the Department of Casualty and Orthopaedics, SRM Medical College Hospital, Chennai, from October 2023 to February 2025. It included 30 patients with femoral fractures. Anthropometric measurements, including the distance from the greater trochanter to the proximal pole of the patella, lateral knee joint line, tip of the olecranon to the tip of the little finger, fibular length combined with femoral head diameter, and patient height, were recorded. The correlations between these measurements and the IM nail size were analysed using Pearson's correlation test.

Results: The mean age of the patients was 40.67±7.89 years, and 63.33% were men. The distance from the olecranon to the tip of the little finger showed the strongest positive correlation with the IM nail size (R=0.81, p-value <0.001), followed by the distance from the greater trochanter to the proximal pole of the patella (R=0.74, p-value <0.001). Fibular length and femoral head diameter together demonstrated a weaker but statistically significant correlation (R=0.41, p-value=0.024). Height showed the weakest correlation with nail length (R=0.37, p-value=0.043).

Conclusion: Anthropometric measurements were significantly correlated with the IM nail length in femur fractures. The olecranon-to-little finger length was the most reliable predictor, followed by the distance from the greater trochanter to the proximal patella and the lateral knee joint line. These findings support the use of anthropometric parameters for preoperative IM nail selection, which may improve surgical outcomes.

Keywords: Femoral shaft fracture, Intramedullary nailing, Nail size, Preoperative planning

INTRODUCTION

Femur fractures, especially those occurring in the diaphyseal region, are prevalent and serious orthopaedic injuries encountered in clinical practice. These fractures often result from high-energy trauma, such as motor vehicle accidents, falls from heights, or sports injuries, and significantly affect a patient's mobility and quality of life [1]. IM nail has become the gold standard treatment for femoral shaft fractures because it effectively stabilises the bone, allowing for early mobilisation and a relatively low complication rate. However, selecting the optimal IM nail length and size is crucial for ensuring proper alignment, promoting healing, and minimising complications. IM interlocking nailing is the established standard for treating femur fractures [2].

An appropriately sized nail prevents irritation of the soft tissue envelope and facilitates the eventual removal of the nail, if necessary. The insertion of a properly sized nail is crucial for achieving optimal results. A shortened nail can cause malreduction and insufficient working length, leading to implant failure [3]. Conversely, an elongated nail may interfere with the fracture site and exert pressure on the patellar tendon, causing pain. Precise nail implantation is essential for preventing these issues. Nail size (length) estimation can be performed preoperatively or intraoperatively [4]. Accurate preoperative nail assessment can help overcome the limitations of current sizing methods, which often rely on intraoperative trial-and-error, leading to increased operative time, higher radiation exposure, and potential technical errors [5]. Various anthropometric parameters aid in the preoperative estimation of femoral nail length. Determining the appropriate IM nail length involves evaluating various patient-specific factors, including femoral geometry and anthropometric measurements, such as femur length, diameter, and cortical thickness [6].

The correlation between these measurements and the IM nail size has profound implications for the efficacy of surgical interventions for femoral fractures. Accurate nail sizing is essential for ensuring mechanical stability, reducing the risk of malalignment, avoiding implant-related complications, and improving overall surgical outcomes [7]. Standard commercially available prostheses may not adequately accommodate all individuals due to significant anatomical diversity among different populations [7]. While norms have been established for Caucasians and Chinese individuals, evidence about Indians is insufficient [8].

The present study aimed to explore the relationship between anthropometric measurements and appropriate IM Interlocking nail size in patients with femoral fractures. This study sought to determine whether certain measurements can predict optimal nail size, thereby enabling a more personalised approach to femoral fracture treatment. By analysing data from various anthropometric parameters and nail sizes used in femoral surgeries, this study aims to fill gaps in the existing literature and contribute to improved preoperative planning and outcomes for patients with femoral fractures.

MATERIALS AND METHODS

This cross-sectional study was conducted in 30 patients in the Department of Casualty and Orthopaedics, SRM Medical College Hospital, Chennai, Tamil Nadu, India, from October 2023 to February 2025. The study was approved (IEC No: SRMIEC-ST0723-1545) by the Institutional Ethics Committee (IEC), and informed consent was obtained from all patients before the study initiation.

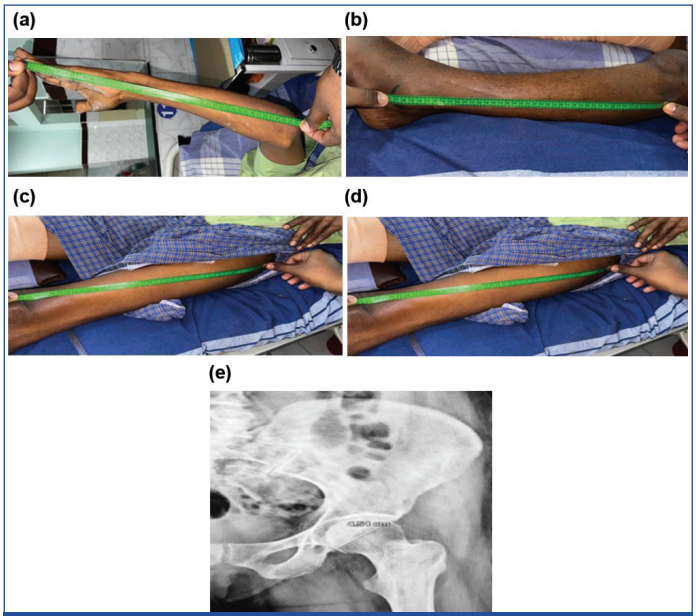
Inclusion criteria: The study included skeletally mature patients, including those with closed and open fractures of the femur, provided that there was an intact, normal femur to serve as an anthropometric reference.

Exclusion criteria: Patients with congenital lower limb abnormalities or limb length shortening, post-polio residual paralysis, previous fractures of the femur or bilateral forearm, hereditary skeletal diseases, skeletal immaturity, or bilateral femur fractures were excluded.

Sample size calculation: The minimum sample size based on Naik MA et al., reported r=0.861 for forearm + little-finger length versus femoral length was calculated using Fisher's z transformation and found to be 8 (α=0.05, power=80%) [9]. The present study used a conservative approach and recruited 30 patients.

Study Procedure

Estimation of Femoral Nail Length Using Anthropometric Measurements [Table/Fig-1a-e]: This study was conducted among patients presenting to the Emergency Room (ER) with femur fractures, which were confirmed radiologically using X-rays of the affected limb. Before shifting to the operating theatre, specific anthropometric measurements were taken on the normal, unaffected limb. These include the distance from the most prominent point of the greater trochanter to the proximal pole of the patella, the distance to the lateral knee joint line, the distance from the tip of the olecranon to the tip of the little finger, the fibular length combined with the femoral head diameter, and the patient's height under appropriate anaesthesia, the patient was positioned for femoral nailing. A suitable nail length was selected such that its proximal end aligns with the tip of the greater trochanter and the distal end with the proximal pole of the patella or distal epiphyseal scar. The selected nail was then inserted, with intraoperative adjustments made as necessary, and secured using interlocking screws [9-11].



[Table/Fig-1]: Depicts the diverse anthropometric measurements obtained from the unaffected limb to ascertain femoral nail length: (a) Distance from the olecranon tip to the little finger tip; (b) Fibular length; (c) Distance from the most prominent point of the greater trochanter to the proximal pole of the patella; and (d) Distance from the greater trochanter to the lateral knee joint line; (e) Radiograph depicting the definitive surgical alignment of the chosen nail in relation to the anatomical landmarks. The attached images were taken from the present study.

STATISTICAL ANALYSIS

Data were presented as mean, standard deviation, frequency and percentage. Continuous variables were compared using the Independent sample t-test. The correlation between continuous variables was determined using Pearson's correlation test. Significance was defined by a p-value less than 0.05 using a two-tailed test. Data analysis was performed using Statistical Package for Social Sciences (SPSS) version 21.0 (IBM-SPSS Science Inc., Chicago, IL).

RESULTS

The mean age of the patients was 40.67±7.89 years, and the mean height was 170.87±7.19 cm. The distance from the greater trochanter to the lateral knee joint line was 46.63±2.30 cm, followed by that from the greater trochanter to the proximal pole of the patella at 43.63±1.65 cm. The mean distance from the olecranon's tip to the little finger's tip was 42.13±1.74 cm. The mean IM nail length was 40.33±1.90 cm, and the sum of fibular length and femoral head diameter was 44.09±1.27 cm on average.

Regarding gender, 19(63.33%) were male and 11(36.67%) were female. A 10 mm IM nail was used in 28(93.33%) patients, whereas 2(6.67%) received an 11mm nail [Table/Fig-2].

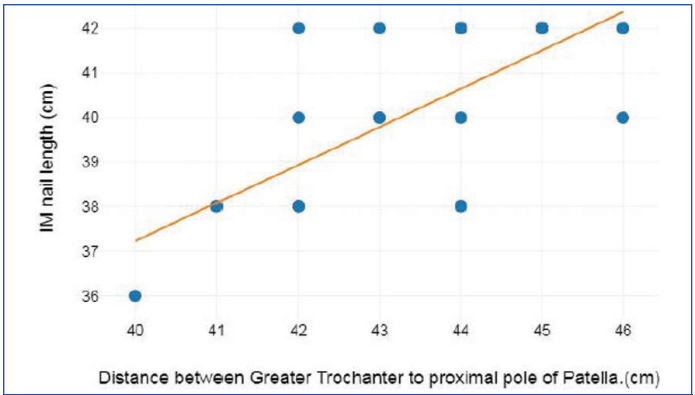
Parameters	Mean±SD
Age (in years)	40.67±7.89
Height (in cm)	170.87±7.19
Greater trochanter to proximal pole of patella (cm)	43.63±1.65
Greater trochanter to lateral knee joint line (cm)	46.63±2.30
Sum of fibular length and femoral head diameter (cm)	44.09±1.27
Tip of olecranon to tip of little finger (cm)	42.13±1.74
Intramedullary (IM) nail length (cm)	40.33±1.90
Gender	**n (%)**
Male	19 (63.33%)
Female	11 (36.67%)
Intramedullary (IM) nail diameter (mm)	**n (%)**
10	28 (93.33%)
11	2 (6.67%)

[Table/Fig-2]: Patient demographics and anthropometric measurements.

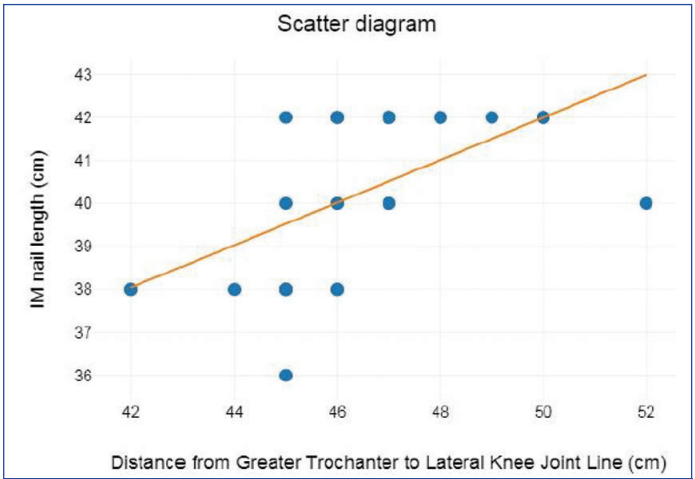
Correlation between IM nail length and patient anthropometric measurements is depicted in [Table/Fig-3]. The distance from the olecranon to the tip of the little finger with IM nail length showed the strongest positive correlation (R=0.81, p-value <0.001), followed by the distance from the greater trochanter to the proximal pole of the patella (R=0.74, p-value <0.001) [Table/Fig-4]. The distance from the greater trochanter to the lateral knee joint line showed a moderate correlation (R=0.60, p-value <0.001) [Table/Fig-5]. The sum of fibular length and femoral head diameter together demonstrated a weaker but statistically significant correlation (R=0.41, p-value=0.024) [Table/Fig-6]. Height showed the least correlation with nail length (R=0.37, p-value=0.043), although it was still significant.

Anthropometric measurements	R (Correlation Coefficient)	p-value
Distance between the greater trochanter and to proximal pole of the patella.	0.74	<0.001
Distance between the prominent point of the greater trochanter to the lateral knee joint line	0.6	<0.001
Sum of fibular length and femoral head diameter (cm)	0.41	0.024
Height (cm)	0.37	0.043
Olecranon to little finger (cm)	0.81	<0.001

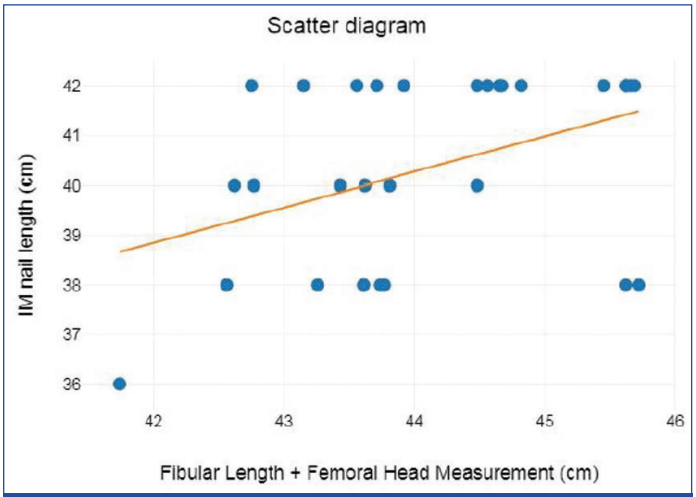
[Table/Fig-3]: Correlation between Intramedullary (IM) nail length and patient anthropometric measurements.



[Table/Fig-4]: Pearson's correlation between Intramedullary (IM) nail length and the most prominent point of the greater trochanter to the proximal pole of the patella.



[Table/Fig-5]: Pearson's correlation of Intramedullary (IM) nail length and the most prominent point of the greater trochanter to the lateral knee joint line.



[Table/Fig-6]: Pearson's correlation of intramedullary (IM) nail length and fibular length plus femoral head diameter.

The distance between the Greater Trochanter (GT) and proximal patella pole showed a strong correlation with nail length (R=0.74, R^2=0.55, β=0.74, B=0.86, p-value <0.001). The distance between the greater trochanter and lateral knee joint line showed a positive association (R=0.60, R^2=0.36, β=0.60, B=0.49, p-value <0.001). Fibular length and femoral head diameter combined showed moderate correlation (R=0.41, R^2=0.17, β=0.41, B=0.71, p-value=0.024). Height showed weaker correlation (R=0.37, R^2=0.14, β=0.37, B=0.10, p-value=0.043). The olecranon to little finger distance showed the strongest correlation (R=0.81, R^2=0.65, β=0.81, B=0.93, p-value <0.001) [Table/Fig-7].

Predictor variables	R	R^2	β (Standardised)	B (Unstandardised)	p-value
Distance between GT and proximal pole of patella (cm)	0.74	0.55	0.74	0.86	<0.001
Distance between GT and lateral knee joint line (cm)	0.6	0.36	0.6	0.49	<0.001
Fibular length + femoral head diameter (cm)	0.41	0.17	0.41	0.71	0.024
Height (cm)	0.37	0.14	0.37	0.1	0.043
Olecranon to little finger distance (cm)	0.81	0.65	0.81	0.93	<0.001

[Table/Fig-7]: Regression models for prediction of femoral IM nail length.

DISCUSSION

This study highlights the significant relationship between various anthropometric measurements and the appropriate selection of IM nail length for femoral fracture stabilisation. The correlation analysis enables accurate preoperative IM nail length estimation, improving surgical efficiency and patient safety. The mean age of the patients was 40.67 years, and the majority were men (63.33%). This demographic pattern is consistent with global trends reported in the trauma literature, where males are more frequently affected by femoral fractures due to higher exposure to trauma and risk-prone activities. Studies have similarly noted a higher prevalence of traumatic fractures among men, reinforcing this study's findings [12,13].

Anthropometric measurements from both the upper and lower limbs were evaluated for their predictive value in determining the IM nail length. The mean distance from the olecranon to the tip of the little finger was 42.13 cm (±1.74 cm), representing an upper limb measurement that can easily be obtained in clinical practice. Naik MA et al., found that forearm and little finger length closely correlate with femoral length, supporting the use of this simple, non radiographic method [9].

Lower limb measurements were also assessed, with the mean distance from the greater trochanter to the proximal pole of the patella measuring 43.63 cm (±1.65 cm), and from the greater trochanter to the lateral knee joint line at 46.63 cm (±2.3 cm). These results are comparable to those reported by Moosa SS et al., who found mean femoral lengths of 436.88 mm in males and 402.38 mm in females [14]. The strong correlation between these femoral measurements and IM nail length in this study (R=0.74 and R=0.6, respectively) underscores the importance of femoral dimensions in nail selection, as also noted by a previous study [15].

The relationship between patient height and IM nail length was moderate in this study (R=0.37, p-value=0.043), with each 11 cm increase in height corresponding to a 3.2 mm increase in nail length. This finding is consistent with the work of Pearson J et al., who reported a correlation of 0.59 between patient height and nail length and supports the notion that height is a useful, although not the most precise, predictor of IM nail size [16]. These studies results (r=0.56) are in line with the previous studies, confirming that height can serve as a quick screening tool when other measurements are not available [17,18].

This study's findings further validate this approach, as there was a strong correlation (R=0.81, p-value <0.001) between the olecranon-to-little finger distance and the IM nail length. This agrees with the findings of Marchand LS et al., and Rogers MJ et al., who also recommended this method for its practicality and reliability, especially when the contralateral femur is unavailable for comparison [19,20].

Another important finding was the moderate correlation between the sum of the fibular length, femoral head diameter, and IM nail length (R=0.41, p-value=0.024). Also, combining these lower limb measurements provides an accurate and reliable estimate of the femoral medullary length, which is essential for selecting the correct IM nail size [21]. The combined mean measurement for the fibula and femoral head length was 44.09±1.1 cm), further supporting the use of these parameters in clinical practice.

In terms of clinical application, this study's findings support the use of non invasive preoperative anthropometric measurements to estimate IM nail length, reducing the need for intraoperative radiographic assessment. Traditional intraoperative methods, which rely on fluoroscopy, expose both patients and surgical staff to unnecessary radiation, increase surgical time, and carry the risk of blood loss if the wrong nail size is selected [22]. Studies such as those by Graves ML and Petro CC and Prabhu AS others highlight the benefits of accurate preoperative planning, which can minimise complications and improve surgical outcomes [23,24].

Regression analysis revealed predictive relationships between anthropometric measurements and femoral IM nail length, with olecranon to little finger distance as the strongest predictor (R=0.81, R^2=0.65, p-value <0.001), explaining 65% of the variance in nail length. The greater trochanter to proximal patella pole distance was the second-best predictor (R=0.74, R^2=0.55, p-value <0.001), while the remaining measurements showed weaker correlations: lateral knee joint line distance (R=0.6, R^2=0.36), combined fibular length and femoral head diameter (R=0.41, R^2=0.17), and height (R=0.37, R^2=0.14). Statistical significance across predictors (p-value ≤0.043) supports the development of standardised preoperative nail length protocols, with olecranon-to-little finger measurement providing optimal accuracy for femoral nail sizing.

Limitation(s)

The limited sample size of 30 patients constrains the generalisability of the findings to a broader population. The single Institution design may introduce regional biases, potentially affecting the applicability of the results to diverse healthcare settings. Although this study concentrated on preoperative IM nail length determination, it did not account for anatomical variables such as bone density and muscle mass, which could impact surgical outcomes. The narrow focus of this study, restricted to preoperative measurements, did not assess long-term outcomes or complications. To validate these findings, larger multicentre studies with extended follow-ups are necessary.

CONCLUSION(S)

The study concluded that anthropometric measurements significantly correlated with IM nail length in femur fractures. The olecranon-to-little finger length exhibited the strongest correlation, establishing it as the most reliable predictor. The distance from the greater trochanter to the proximal patella and lateral knee joint line also showed strong predictive values. The fibular length to femoral head diameter and height showed moderate correlations with these significant findings, supporting the use of these anthropometric parameters for preoperative IM nail selection, which may improve the surgical outcomes.

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