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ANATOMICAL EVALUATION OF OPTIMAL PLATE POSITIONING FOR DISTAL FEMUR LOCKING COMPRESSION PLATES: A CADAVERIC STUDY IN THE INDIAN POPULATION

Orthopaedics

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ABSTRACT

Background: Anatomically pre-contoured distal femur locking compression plates (DF-LCP) are based on Western morphometric data and may not fit Indian femora accurately, risking intra-articular screw penetration or posterior cruciate ligament (PCL) impingement. **Objective:** To identify the optimal DF-LCP position using consistent bony landmarks in Indian femora. **Methods:** Forty-eight adult cadaveric femora were studied. DF-LCPs from three manufacturers were applied at four positions relative to the lateral epicondyle—S3 (3 mm superior), I3 (3 mm inferior), 0 (neutral), and A3 (3 mm anterior). Radiographic and clinical assessments, including notch-view imaging, evaluated screw penetration and PCL proximity. **Results:** Overall screw penetration was 54.2 %. The S3 position had 0 % penetration, while I3 had 100 %. Shorter femora (36 ± 3 cm) showed more penetration than longer ones (42 ± 3 cm). **Conclusion:** Placing the DF-LCP about 3 mm proximal to the lateral epicondyle (S3 position) minimizes joint and PCL violation. Intra-operative notch-view verification and plate designs based on Indian morphology are recommended.

KEYWORDS

Distal Femur Fracture Fixation; Locking Compression Plate; Anatomical Landmarks; Screw Penetration; Indian Population; Cadaveric Study

INTRODUCTION

Fractures of the distal femur account for roughly 3 – 6 % of all femoral fractures and less than 1 % of total skeletal fractures[1]. They show a bimodal age distribution, occurring in young adults following high-energy trauma and in the elderly due to low-energy mechanisms such as falls.

Over the past two decades, a deeper understanding of distal femoral anatomy, fracture biology, and biomechanics[7] has led to the development of various fixation devices[2] — external fixators, fixed-angle implants, intramedullary nails, and locking compression plates. Among these, the distal femur locking compression plate (DF-LCP) has become the implant of choice for most surgeons because it allows for anatomical reduction, angular stability, and biological fixation[3].

However, most commercially available DF-LCPs are pre-contoured using Western morphometric databases[5,6]. This creates a potential mismatch when applied to Indian femora, particularly in female or smaller bones, leading to complications such as intra-articular screw penetration, posterior cruciate ligament (PCL) impingement, and malalignment. Clinical reports note postoperative knee stiffness and motion restriction[6], supporting the need for regional morphometric validation[4].

Hence, it is essential to define optimal plate placement using easily identifiable bony landmarks to avoid iatrogenic injury while ensuring stability. To date, no published Indian study has systematically analysed the positional relationship between DF-LCP holes and distal femoral condylar anatomy. Anatomical variations among Indian femora, including condylar width and shaft valgus angle, warrant customized evaluation of plate contouring.

This cadaveric study was therefore designed to:

1. Determine the optimal location of the DF-LCP on the distal femur relative to reproducible anatomical landmarks.
2. Identify screw holes at risk of intra-articular penetration or PCL impingement.
3. Propose an evidence-based guideline for safe plate positioning suitable for the Indian population.

MATERIALS AND METHODS

This descriptive cadaveric study was conducted in the Cadaveric Skills Laboratory of the Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai, in collaboration with the Institute of Anatomy, Rajiv Gandhi Government General Hospital.

A total of 60 skeletally mature adult femora were procured for morphometric assessment. Following exclusion of specimens with deformities, fractures, or erosion, 48 femora were selected for the final analysis.

Grouping of Specimens:

Based on the measured distance from the tip of the greater trochanter to the distal condylar line, femora were divided into two groups:

- Group A: Mean length 42 ± 3 cm (n = 24; 12 right, 12 left)
- Group B: Mean length 36 ± 3 cm (n = 24; 12 right, 12 left)

This classification helped account for variations in bone size, avoiding errors related to gender or population bias.

Implants Used:

Right and left Distal Femur Locking Compression Plates (DF-LCP) were obtained from three manufacturers:

- Tetramed Surgicals,
- Sharma Orthopaedics™, and
- Exactech Inc.

Each plate consisted of a shaft portion (similar to a broad dynamic compression plate with combi holes) and a spoon-shaped distal portion designed to match the distal femoral contour.

Method of Plate Positioning:

Each femur was mounted securely on a custom stand, exposing the lateral surface.

Two reference lines were marked:

1. The long axis of the distal femoral shaft.
2. A perpendicular line drawn from the lateral epicondyle to intersect the shaft axis.

From this point of intersection, four potential positions for the central distal hole of the DF-LCP were identified:

- S3: 3 mm superior to the intersection point
- I3: 3 mm inferior
- 0: Neutral position
- A3: 3 mm anterior

Plates were sequentially applied in these four positions on each specimen.

Fixation and Assessment:

Fixation was performed initially with one cancellous screw through the distal central hole and one cortical screw proximally.

Subsequently, the posteroinferior and inferior locking holes were drilled and filled with locking cancellous screws (Figure 1).

Each configuration was evaluated clinically and radiographically to assess:

- Screw trajectory and potential intra-articular penetration,
- Posterior cruciate ligament (PCL) impingement, and
- Plate conformity to the distal femoral contour.

Radiographic Evaluation:

Standard anteroposterior, lateral, and notch-view radiographs were taken.

The notch view was obtained with approximately 40° knee flexion and a cephalad beam projection onto the distal femur to visualise the intercondylar region and detect screw violations (Figure 2).

Data Recording and Analysis:

For each femur–plate combination, screw penetration was recorded as either present or absent.

Observations were tabulated according to plate position, side, group, and manufacturer.

The data were expressed as percentage incidence of screw penetration for comparative interpretation.

RESULTS

A total of 48 cadaveric femora were analyzed using distal femur locking compression plates (DF-LCP) obtained from three different manufacturers. The observations were grouped according to the implant position, bone length category, and laterality.

Overall Findings

The total incidence of intra-articular screw penetration from the inferior and postero-inferior holes of the distal end of the plate was 54.16 %.

Left-sided femora demonstrated a slightly higher rate of penetration (58.3 %) than right-sided femora (50 %).

Among the length-based groups, Group B (shorter femora, 36 ± 3 cm) had a higher penetration rate of 62.5 %, whereas Group A (longer femora, 42 ± 3 cm) showed a rate of 45.8 %.

Irrespective of plate brand or laterality, the S3 position consistently produced zero screw penetration, while the I3 position resulted in 100 % penetration.

Intermediate positions (0 and A3) showed screw penetration in 58.3 % of specimens.

A total of 48 cadaveric femora were analyzed across various positional and manufacturer combinations.

The incidence of screw penetration varied notably with the position of the distal femur locking compression plate (DF-LCP).

As shown in Table 1, the S3 position, where the central distal hole was placed 3 mm superior to the lateral epicondyle, demonstrated no intra-articular screw penetration (0 %) in any specimen.

In contrast, the I3 position (3 mm inferior) consistently produced 100 % screw penetration, confirming that inferior placement markedly increases the risk of joint violation.

The neutral (0) and anterior (A3) positions both showed 58.3 % penetration rates, indicating that these placements are also suboptimal compared to the superior position.

When stratified by bone length, Group B (shorter femora, 36 ± 3 cm) demonstrated a higher rate of penetration (62.5 %) compared to Group A (42 ± 3 cm, 45.8 %).

This finding suggests that smaller femora, often representative of the Indian population, are more susceptible to screw misdirection due to plate contour mismatch.

Regarding laterality, left femora (58.3 %) showed a marginally higher penetration rate than right femora (50 %), though the difference was not statistically significant.

Similarly, there was no meaningful variation among the three plate manufacturers (Tetramed, Sharma Orthopaedics™, and Exactech Inc.), each averaging a penetration rate of approximately 54 %. This confirms that implant design had minimal influence, and that plate positioning relative to the lateral epicondyle was the critical determinant of safe fixation.

Thus, the S3 position provided the most favorable trajectory, independent of manufacturer or laterality.

Figure 1: Notch-view photograph of distal femur showing intra-articular screw penetration when the DF-LCP is placed inferiorly (I3 position).

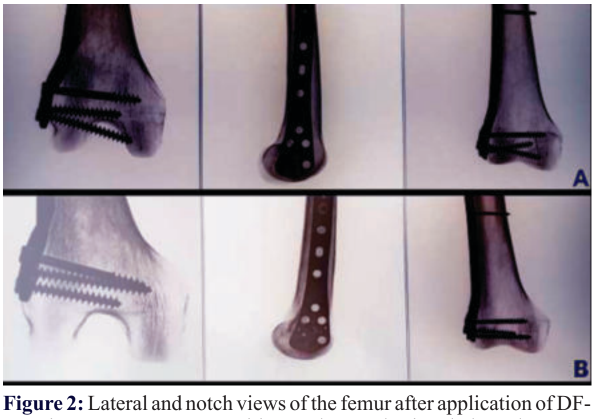

Figure 2: Lateral and notch views of the femur after application of DF-LCP in 0 [A] & S3 [B] positions. The notch view below shows no screw penetration while there is screw penetration in the notch view above with 0 position of DF-LCP.

Table 1: Consolidated Summary of Screw Penetration Incidence Based on Plate Position, Femur Group, and Side

Variable	Category	No. of Specimens	Screw Penetration (%)
Plate Position	S3 (3 mm superior)	12	0
	0 (Neutral)	12	58.3
	A3 (3 mm anterior)	12	58.3
	I3 (3 mm inferior)	12	100

Femur Group	Group A (42 ± 3 cm)	24	45.8
	Group B (36 ± 3 cm)	24	62.5
Side	Right	24	50
	Left	24	58.3
Manufacturer	Tetramed	16	54.2
	Sharma OrthopedicsTM	16	54.2
	Exactech Inc.	16	54.2

Note: 'S3' = 3 mm superior to lateral epicondyle; '0' = neutral position; 'A3' = 3 mm anterior; 'I3' = 3 mm inferior. No significant difference was observed among manufacturers.

DISCUSSION

Although the distal femur locking compression plate (DF-LCP) is widely used for distal femoral fractures, its Western-based design often leads to contour mismatch when applied to Indian femora, particularly in smaller-built individuals and females, resulting in intra-articular screw penetration, posterior cruciate ligament (PCL) impingement, and loss of motion.

In the present study, a systematic cadaveric evaluation was performed to define the optimal positioning of DF-LCP using easily identifiable bony landmarks.

Our results confirmed that the superior position (S3)—where the central distal hole of the plate is placed about 3 mm proximal to the lateral epicondyle along the femoral long axis—was consistently the safest position, with no screw penetration noted in any specimen.

Conversely, when the plate was shifted inferiorly (I3 position), screw trajectory frequently breached the intercondylar notch, with a 100 % incidence of intra-articular violation.

This correlation underscores the importance of precise vertical placement rather than minor mediolateral or anterior shifts.

Comparable findings were reported in earlier morphometric and cadaveric studies from East-Asian populations[5], which demonstrated a similar risk of malalignment when Western pre-contoured plates were used.

Kistler et al. observed a high rate of PCL damage (≈ 89 %) when bicondylar screws were inserted through the most distal posterior holes of conventional DF-LCPs[8].

Our study reinforces these findings and provides quantitative confirmation on Indian bones, showing that minor deviations in plate placement can drastically alter screw exit trajectories.

The present data also highlight the influence of bone size on screw direction. Shorter femora (Group B) recorded a higher screw penetration rate (62.5 %), suggesting that the current plate contour may be oversized for smaller bones.

This observation has direct clinical implications in India, where anthropometric variation is wide and the average femoral length is shorter than Western norms.

Customized or variable-angle plates, designed according to regional morphometry, could therefore minimize implant–bone mismatch and improve outcomes[12].

No significant difference was observed among the three plate manufacturers, indicating that plate design uniformity rather than manufacturer-specific geometry influences screw direction.

The relationship between intercondylar notch width and ligament impingement has also been described[9].Similarly, the slight predominance of penetration on the left side is likely due to minor asymmetry in femoral torsion and condylar flare, which are known anatomical variations described by Hirtler et al.[13].

The use of an intra-operative notch view—simulating approximately 40° of knee flexion with cephalad projection—proved valuable in detecting potential screw penetration, aligning with findings from Liu et al.[10].

Routine employment of this view can serve as a low-cost, radiation-efficient safeguard during distal femoral fixation, especially in setups lacking advanced imaging. Future finite-element or CT-based morphometric modeling could complement this cadaveric validation. The findings of this study therefore offer practical intra-operative guidelines readily applicable to Indian orthopaedic practice. Similar anatomical guideline frameworks have been reported in upper-limb plating studies, supporting the reliability of landmark-based positioning[14].

Clinical Implications

- Position the plate 3 mm proximal to the lateral epicondyle.
- Avoid posterior-inferior holes or use variable-angle screws.
- Employ notch-view imaging intra-operatively for safety verification.
- Encourage population-specific implant redesign.

Limitations

This study involved cadaveric femora without soft-tissue envelope simulation; hence, dynamic intra-operative factors were not replicated.

Only short-term mechanical outcomes (screw trajectory and penetration) were analysed—functional outcomes could not be assessed.

Despite these limitations, the sample size and uniform methodology provide a reliable anatomical basis for future clinical validation.

CONCLUSION

The present cadaveric analysis establishes a clear, reproducible guideline for optimal positioning of the distal femur locking compression plate (DF-LCP) in the Indian population. Positioning the central distal hole approximately 3 mm proximal to the lateral epicondyle (S3 position) provides the most favourable screw trajectory, avoiding intra-articular penetration and posterior cruciate ligament impingement.

This relationship holds true irrespective of plate manufacturer or side, emphasizing that accurate anatomical alignment rather than implant design determines fixation safety.

Routine use of an intra-operative notch view is recommended to identify potentially hazardous screw trajectories.

Future design modifications of DF-LCPs, considering Indian anthropometric data, could significantly enhance contour compatibility and minimize iatrogenic complications.

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Conflict of Interest

The authors declare no conflict of interest related to this study.

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