

Analysis Of Parameters For The Optimal Positioning Of Anatomical Lcp In Distal Femur - An Anatomic Study

Dr. Mohan Ganesan¹, Dr. Buvanesh Janakiraman², Dr. N. Deen Muhammad Ismail³, Dr. N. P. Jayaoviya⁴

¹MBBS, MS Orth, DNB Orth, MCh Orth Associate Professor Emergency Department ACS Medical College and Hospital Mail Id: dr_gmohan@yahoo.com, corresponding author

²MBBS, MS Orth Senior Resident Department of Orthopaedics Bhaarith Medical College & Hospital, (A unit of BIHER), Chennai, Tamil Nadu Mail Id: buvanesh18594@gmail.com

³MBBS, MS Orth, D Orth Retd Professor Institute of Orthopaedics and Traumatology Madras Medical College, Chennai, Tamil Nadu Mail Id: drndmi@gmail.com

⁴MBBS Junior Resident Institute of Orthopaedics and Traumatology Madras Medical College, Chennai, Tamil Nadu Mail Id: npjoviya@gmail.com

DOI: 10.47750/pnr.2023.14.02.118

Abstract

Background

Advancement in the understanding of the anatomy of distal femur and fracture healing biology have led to the development of various implant designs optimizing the successful treatment of these injuries. Proper fit and positioning of the implant are mandatory to avoid complications such as intra-articular screw penetration, PCL impingement, etc. DF-LCP [Distal femur - Locking compression plate], an anatomical plate used currently has been developed based on skeletal measurements from the western world. This study aims to determine the optimal position of LCP with the anatomical landmarks, identify problem screws and recognize the use of intraoperative notch view to assessing screw placement. This has not been attempted before as evidenced by the available literature.

Materials and methods

48 adult femurs harvested from cadavers were grouped based on the length and side [group A – 42 +/-3cm & group B – 36 +/-3cm]. DF-LCP from 3 different manufacturers were fixed in 4 different positions [S3, I3, O, A3] with respect to the lateral epicondyle and the long axis of the distal femur. Clinical and radiographic assessment were done to assess the positions of the plate with intra-articular screw penetration.

Results

The total incidence of screw penetration with inferior and postero-inferior locking screws of the distal end of plate was found to be 54.16 %. Irrespective of implant and side variation, superior position (S3) had better results with zero screw penetration. 100% screw penetration was encountered in the inferior position (I3).

Conclusion:

The positioning of the central hole of DF-LCP 3mm proximal to lateral epicondyle along the long axis of distal femur or avoidance of inferior and posterior screw holes of LCP can prevent intra-articular screw penetration. An intraoperative notch view to recognize screw placement can be done. Designing a plate without compromising stability for the Indian population will be more effective.

Keywords Anatomical analysis, Distal femur, Plate positioning, DF-LCP

INTRODUCTION

Fractures of the distal femur represent 3 to 6 % of the femur and less than 1% of all fractures. These fractures have a bimodal age distribution with a peak in young age who undergo high energy trauma and in elderly with a low energy mechanism. Steady advances in our understanding of the anatomy of distal femur and fracture healing biology have led to the development of various implant designs optimizing the successful treatment of these injuries. They range broadly from external fixation, fixed-angle device (blade or sliding barrel implants), plate fixation (locked and unlocked), intramedullary nailing, arthroplasty, and distal femoral replacement (DFR). These modalities have their own merits and demerits^[1].

Anatomy of Distal Femur

The area of the distal femur is defined as the zone between the femoral condyles and the junction of the metaphysis with the femoral diaphysis. The shaft of the femur is cylindrical and at the lower end, it broadens into two curved condyles. If viewed on end, the shape of the distal femur is trapezoidal with the posterior part of the condyle wider than the anterior creating about 25-degrees inclination angle on the medial surface, 15-degrees inclination on the lateral surface and 10-degrees slope on the superior surface. Posteriorly, the condyles are separated by the intercondylar fossa that gives attachment to the cruciate ligaments of the knee.

Modern locking plates are the implants of choice of most surgeons. These plates however were not designed for the Indian population [particularly in females with comparatively smaller bones]. An evaluation done in a series of patients with restriction of knee movements following distal femoral fracture fixations with DF-LCP concluded that they had arthrofibrosis and occult PCL impingement. This made us rethink and come up with a study to define optimal position of DF-LCP, identify problem screws in Indian population. This has not been attempted before as evidenced by the available literature^[2].

MATERIALS AND METHODS

Cadaveric skills lab, Institute of Orthopedics and Traumatology, Madras Medical College, Rajiv Gandhi Govt. General Hospital was the study center. 60 skeletally mature femurs were procured from the Institute of Anatomy, Madras Medical College, and Rajiv Gandhi Govt. General Hospital. Femurs of both sides were grouped according to their measured lengths. Of the obtained 60 femurs, 48 were found to be suitable for the study. Extremely short and long femurs were excluded from the study to prevent errors. Based on the length between the tip of the greater trochanter and distal condylar line, 48 femurs were divided into two groups; Group A: 42 +/- 3 cm = 24 femurs (Right-sided – 12, Left-sided – 12), Group B: 36 +/- 3 cm = 24 femurs (Right-sided – 12, Left-sided – 12). Right and left-sided distal femur locking compression plates from 3 different manufactures were procured for the study; Exactech Inc, Tetramedsurgicals, SHARMA Orthopedic.TM

Distal femur locking compression plates has a shaft and spoon part. Shaft is similar to broad dynamic compression plate with combi holes and is curved to match the curvature of the femur. The combi holes have slots for accommodating both cortical and locking screws. The spoon portion is designed to fit the anatomy of distal femur. The selected femurs were firmly fixed onto a mounting device such that the lateral surface of the femur was accessible to us. A line was drawn along the long axis of the distal femur and a line perpendicular to this long axis was marked connecting it to the lateral epicondyle. 3 points were marked at 3mm intervals proximal, distal and anterior to the point of intersection of two lines on the femur thus creating 4 possible positions [S3, I3, 0, A3] for the central hole of the distal end of DF-LCP.

DF – LCP was positioned over the lateral surface of the distal femur such that the distal end was well seated over the lateral femoral condyle and the proximal end was centred over the femoral shaft proximally. The centre hole of the distal end was adjusted to lie over the intended position as mentioned above [0, S3, I3 & A3]. Fixation was done initially by inserting a cancellous screw through the centre hole distally and a cortical screw proximally. Under careful monitoring the postero-inferior and inferior screw holes of the distal end of DF – LCP were drilled and filled with locking cancellous screws. Clinical and radiographic evaluation were done to assess intra-articular screw penetration and the possibility of PCL impingement in all positions after fixation.

Radiographic evaluation with notch view was done by maintaining a simulated knee flexion of 40 degrees to femur bone and cephalad projection of x-ray beam onto the distal femur with LCP inposition.

RESULTS:

A total of 48 femur were analyzed with their corresponding DF - LCP, obtained from three different manufactures (Table 1). The total incidence of screw penetration with inferior and postero-inferior locking screws of the distal end was found to be 54.16 %.Increased screw penetration was observed with left sided femur in comparison with right sided femurs. Left sided femurs faced a screw penetration rate of 58.33% while 50% was observed in right sided femurs (Figure 1).Group B encountered increased screw penetration rates (62.5%) than Group A (45.83%).Irrespective of implant and side variation, superior position (S3) had superior results with zero screw penetration (Figure 2). Followed by center (O) and anterior (A3) points, with 58.33% of screw penetration each. 100% screw penetration was encountered in the inferior point (I3) (Figure 3).

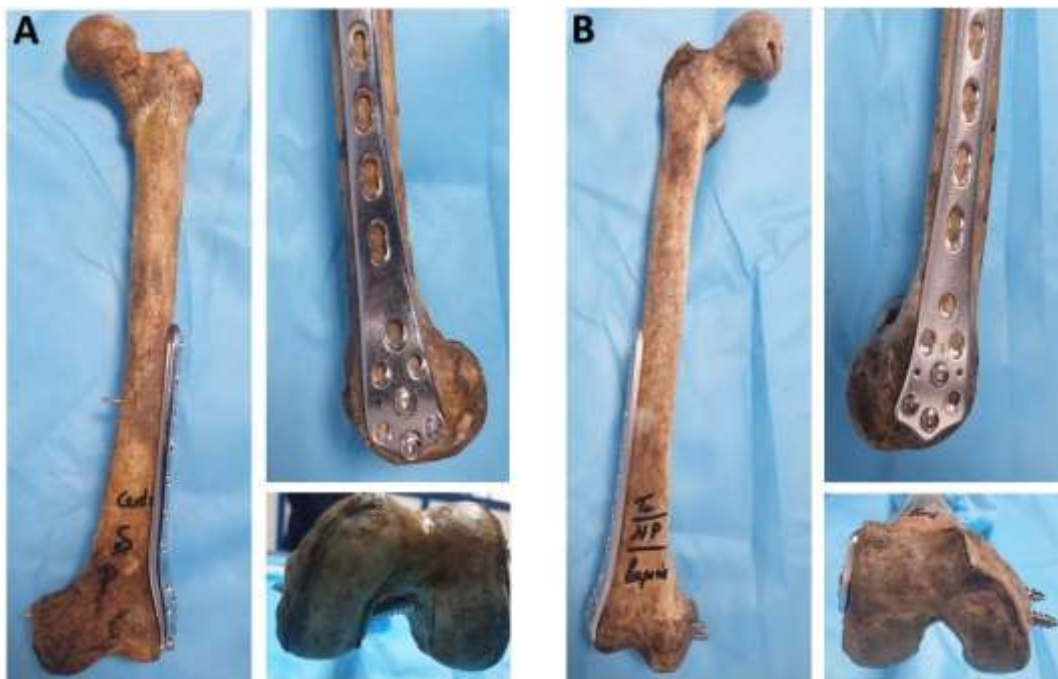


Figure 1:Complications which may occur when the available plate [marked A] is placed according to their contour onto the bone of the Indian population. The plate [marked BTetramedsurgicals] placed in S3 position which do not exhibit intra-articular screw penetration.

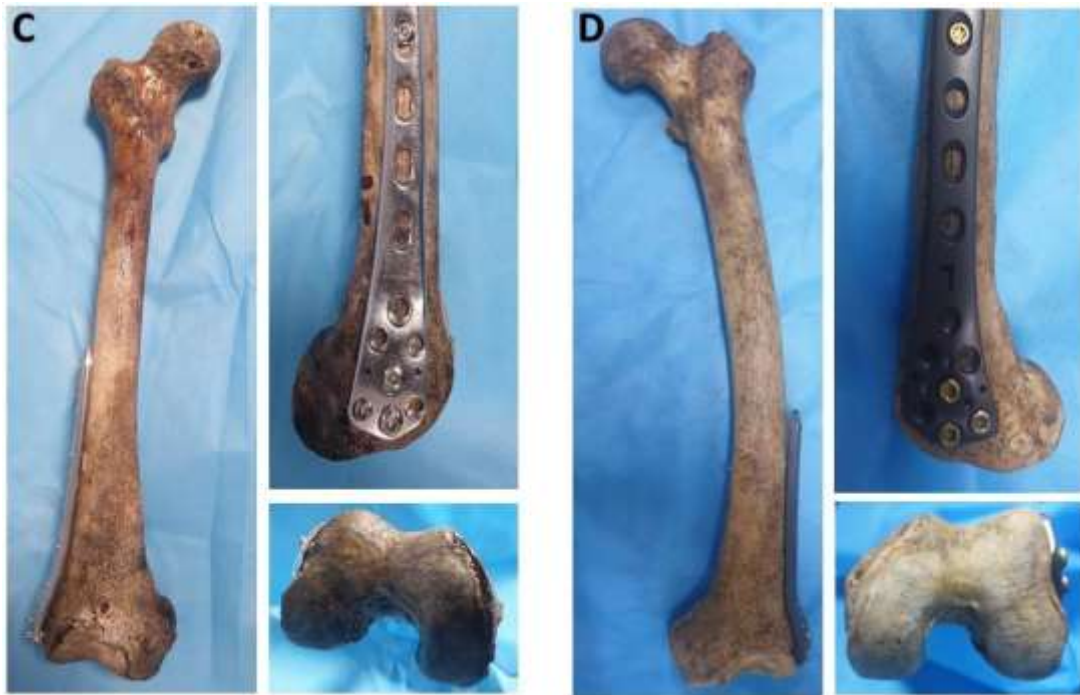


Figure 2: Difference between the Plates: The plates marked C – SHARMA Orthopedic™ and D – Exactech Inc] placed in S3 positions which do not exhibit intra-articular screw penetration.

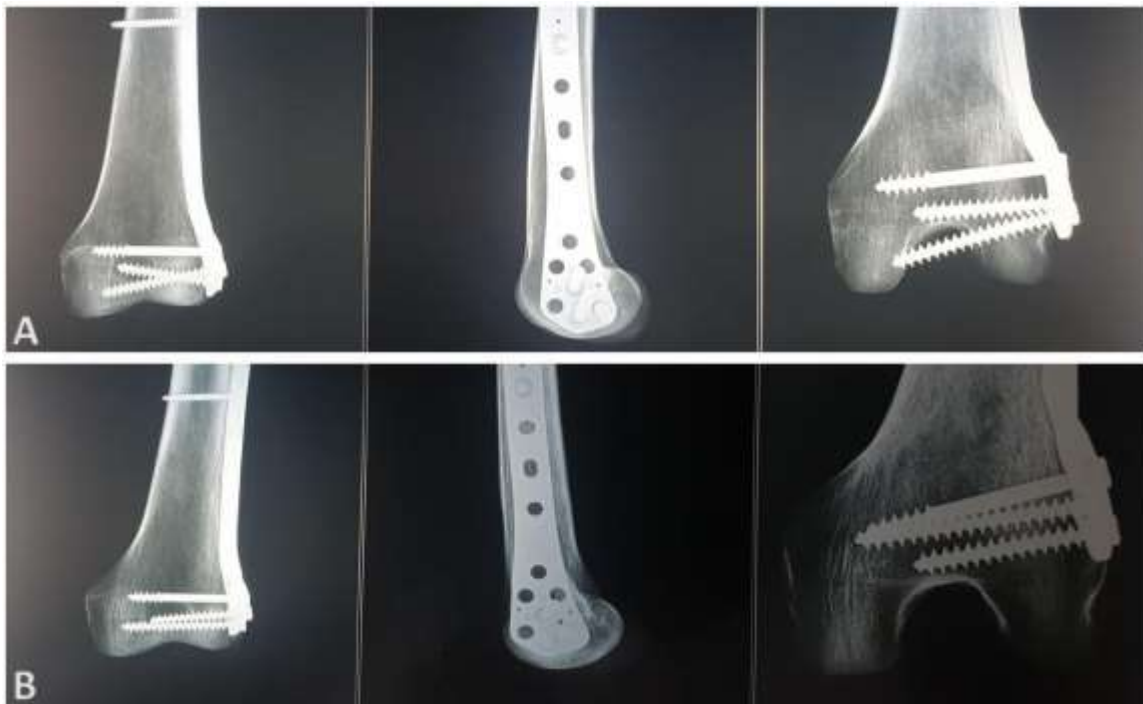


Figure 3: Lateral and notch views of the femur after application of DF-LCP in 0 & S3 [B] positions. The notch view below shows no screw penetration while there is screw penetration in the notch view above with 0 position of DF-LCP

Table 1: Recorded observations in 48 femurs with DF – LCP from three different manufactures including SHARMA Orthopedic™, Tetramedsurgicals & ExactechInc

S No	Implant	Position	Group	Side	Screw penetration	S No	Implant	Position	Group	Side	Screw penetration
1	Tetramed	S3	A	R	-	25	SHARMA	S3	A	L	-
2	Tetramed	I3	A	R	+	26	SHARMA	I3	A	L	+
3	Tetramed	0	A	R	-	27	SHARMA	0	A	L	+
4	Tetramed	A3	A	R	+	28	SHARMA	A3	A	L	-
5	Tetramed	S3	B	R	-	29	SHARMA	S3	B	L	-
6	Tetramed	I3	B	R	+	30	SHARMA	I3	B	L	+
7	Tetramed	0	B	R	+	31	SHARMA	0	B	L	-
8	Tetramed	A3	B	R	-	32	SHARMA	A3	B	L	+
9	Tetramed	S3	A	L	-	33	Exactech	S3	A	R	-
10	Tetramed	I3	A	L	+	34	Exactech	I3	A	R	+
11	Tetramed	0	A	L	-	35	Exactech	0	A	R	-
12	Tetramed	A3	A	L	+	36	Exactech	A3	A	R	-
13	Tetramed	S3	B	L	-	37	Exactech	S3	B	R	-
14	Tetramed	I3	B	L	+	38	Exactech	I3	B	R	+
15	Tetramed	0	B	L	+	39	Exactech	0	B	R	+
16	Tetramed	A3	B	L	+	40	Exactech	A3	B	R	+
17	SHARMA	S3	A	R	-	41	Exactech	S3	A	L	-
18	SHARMA	I3	A	R	+	42	Exactech	I3	A	L	+
19	SHARMA	0	A	R	+	43	Exactech	0	A	L	+
20	SHARMA	A3	A	R	-	44	Exactech	A3	A	L	-
21	SHARMA	S3	B	R	-	45	Exactech	S3	B	L	-
22	SHARMA	I3	B	R	+	46	Exactech	I3	B	L	+
23	SHARMA	0	B	R	-	47	Exactech	0	B	L	+
24	SHARMA	A3	B	R	+	48	Exactech	A3	B	L	+

DISCUSSION

Achievement of acceptable functional outcomes for surgically treated distal femur fractures has been a challenge to Orthopedic surgeons. Management of distal femur fractures initially involved conservative management with plaster immobilization and traction. Later external fixation, fixed angled devices showed promising results. With the introduction of concepts of locking plates, anatomical reduction and biological fixation, DF – LCP became popular and has been gold standard for the management of distal femur fractures ever since. However, these implants were made after extensively studying the western population^[3-7].

Jin Ho Hwang and his colleagues in 2012 from Korea, used longer distal femur locking plates in sixty adult cadaver femur. They established a rather consistent pattern of mismatch at the proximal part with increase valgus malalignment at fracture site if attempts were made to correct this mismatch. Dong Wookson and his investigators in 2018, Korea extensively studied the risk factors for knee stiffness in distal femoral fracture and concluded that extensor mechanism injury has been a major factor for the development of knee stiffness. Kistler BJ and his fellow Scientists studied in six cadavers knee the violation of intercondylar notch during femoral plating. They showed an 88.9% damage of PCL when bicondylar screw were used in the most distal posterior screw holes of Synthes LCP condylar plates. They recommended use of unicondylar screws in the same hole putting stability of the implant and strength of fracture fixation under question. We attempted to establish a universal landmark for proper placement of distal femur locking plates^[8-12].

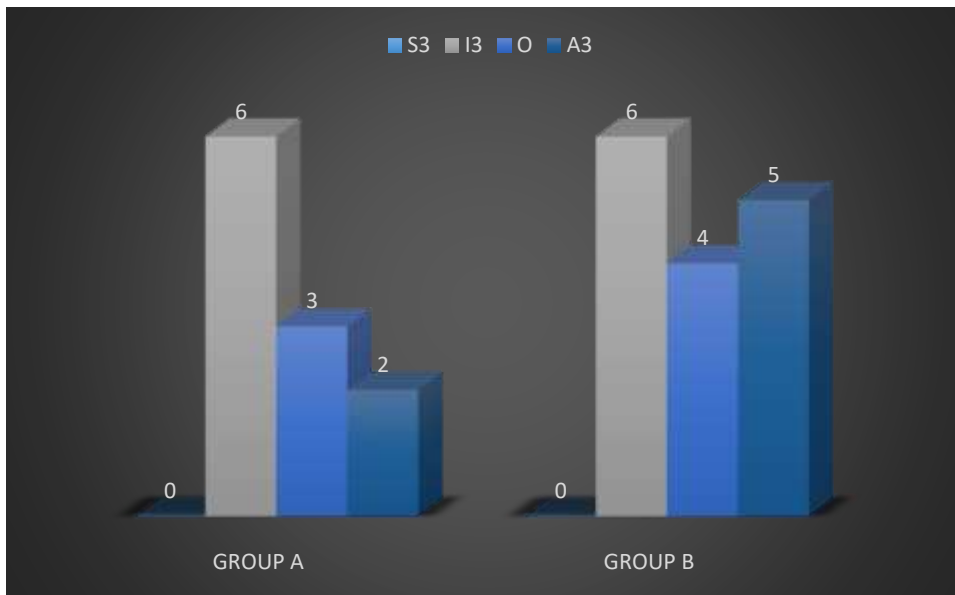


Figure 4: The incidence of screw penetration based on length of femur and position of DF - LCP

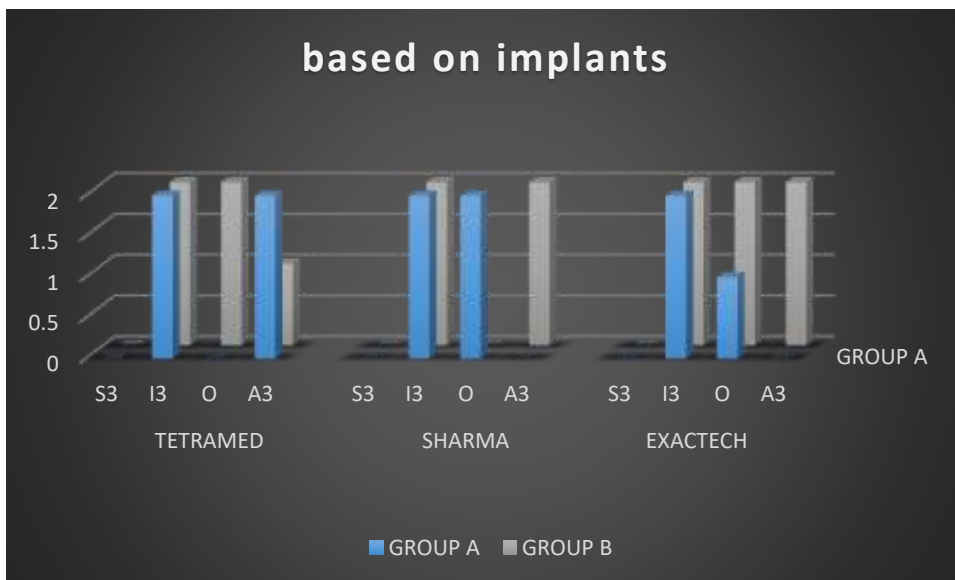


Figure 5: Incidence of intraarticular penetration with various implants used in the study

In our analysis, no significant difference with respect to implant manufactures were observed. Left sided femur had increased rates of screw penetration into the intercondylar notch than right sided femurs. We thus aimed to come up with a fixed landmark in the lateral surface of distal femur that eliminates intercondylar notch penetration and PCL impingement.

Tip of greater trochanter to distal condylar line were used as a standard to group patients in an attempt to overcome gender bias. Condylar parameter (notch width, inter - epicondyle distance, trans epicondyle axis) were excluded since these parameters might get affected in extensive communiton of the distal femur. Femurs were grouped into Group A and Group B. Group B (relatively smaller femurs) have increased screw penetration rates (62.5%) in comparison with Group A (45.83)(relatively larger femur) (Figure 4and 5). This emphasizes the need for reduction in implant size for smaller femurs or change in position during implantation. For increased precision, we attempted to standardize with 3mm points superior, inferior, and anterior to the point of intersection of lines from the distal femoral shaft axis and a line perpendicular extending from the lateral epicondyle. Irrespective of size, side, and implant, the superior point has shown better results with no intercondylar notch penetration. Since lateral epicondyle and shaft axis can be easily made out after anatomical reduction of the

condyles, this could be potential landmark for safe implantation of distal femur locking plates and warrants further evaluation. We suggest that a new implant made as per anthropometric measurements of the Indian population could be effective. Finally, we recommend our technique of placement of DF-LCP [even without image intensifier guidance] or employ notch view intraoperatively to rule out screw penetration. One can also avoid placement of posterior and inferior screws of fixed angle LCP or use VA DF-LCP [Variable angle Distal femur LCP]^[13-15].

CONCLUSION

An approach towards positioning of DF-LCP particularly without image intensifier guidance and avoiding such complications have not been attempted before in literature from this part of the country. The positioning of the central hole of DF-LCP 3mm proximal to lateral epicondyle [S3 position] along the long axis of the distal femur can be performed with a better outcome. The use of intraoperative notch view to recognize screw placement or avoidance of inferior and posterior screw holes can prevent intra-articular screw penetration. Designing a plate without compromising stability for the Indian population to avoid such complications will be more effective. Further investigations are required; Abnormal bowing of femur interferes with proper positioning of DF-LCP, Variation of intercondylar notch, wherein age and gender play a major role. With increasing age, intercondylar notch narrows and females have a narrow intercondylar notch compared to males for a particular age. This increases the chance for occult PCL impingement following DF-LCP fixation in elderly females. In future, mismatch of proximal aspect of the distal femur locking plates and femur may be analysed for the further development of our study.

REFERENCE

1. Martinet O, Cordey J, Harder Y, Maier A, Bühler M, Barraud GE. The epidemiology of fractures of the distal femur. *Injury*. 2000;31(SUPPL.3).
2. Hake ME, Davis ME, Perdue AM, Goulet JA. Modern Implant Options for the Treatment of Distal Femur Fractures. *J Am Acad Orthop Surg*. 2019;27(19):E867–75.
3. Gangavalli AK, Nwachuku CO. Management of Distal Femur Fractures in Adults. An Overview of Options. *Orthop Clin North Am*. 2016;47(1):85–96.
4. Virk JS, Garg SK, Gupta P, Jangira V, Singh J, Rana S. Distal femur locking plate: The answer to all distal femoral fractures. *J Clin Diagnostic Res*. 2016;10(10):RC01–5.
5. Hwang JH, Oh JK, Oh CW, Yoon YC, Choi HW. Mismatch of anatomically pre-shaped locking plate on asian femurs could lead to malalignment in the minimally invasive plating of distal femoral fractures: A cadaveric study. *Arch Orthop Trauma Surg*. 2012;132(1):51–6.
6. Son D-W, Kim H-S, Choi W-Y. Risk Factors for Knee Stiffness in Distal Femoral Fractures. *J Korean Fract Soc*. 2018;31(4):123.
7. Pp B, Hy K. Poster No . 1965 • 56th Annual Meeting of the Orthopaedic Research Society. 1965;(1646):1965.
8. Rockwood C, Green D. Fracture in adults. 4th ed. Philadelphia; 1996.
9. Rhimes an ABCS production ; S; created by S. Grey's anatomy. Complete ninth season [Internet]. Burbank, Calif. : Distributed by Buena Vista Home Entertainment, 2013.; 2013. Available from: <https://search.library.wisc.edu/catalog/9910544455902121>
10. Śmigielski R, Zdanowicz U, Drwięga M, Ciszek B, Williams A. The anatomy of the anterior cruciate ligament and its relevance to the technique of reconstruction. *Bone Joint J*. 2016;98-B(8):1020–6.
11. Liu B, Zuelzer DA, Allen J, Comadoll S, Hsu JR, Swart EF, et al. Can the use of femoral notch view alone decrease measurement error of distal interlocking screws after retrograde femoral nailing. *Injury* [Internet]. 2019;50(4):962–5. Available from: <https://doi.org/10.1016/j.injury.2019.03.012>
12. Yeap E., Deepak A. Distal Femoral Locking Compression Plate Fixation in Distal Femoral Fractures: Early Results. *Malaysian Orthop J*. 2007;1(1):12–7.
13. McDonald TC, Lambert JJ, Miles Hulick R, Graves ML, Russell G V., Spitler CA, et al. Treatment of Distal Femur Fractures With the DePuy-Synthes Variable Angle Locking Compression Plate. *J Orthop Trauma*. 2019;33(9):432–7.
14. Hirtler L, Rohrich S, Kainberger F. The femoral intercondylar notch during life: An anatomic redefinition with patterns predisposing to cruciate ligament impingement. *Am J Roentgenol*. 2016;207(4):836–45.
15. G M, M N, K R. Anatomical Analysis of Guidelines for Optimal Plate Placement in Volar and Dorsal Aspects of Distal Radius. *J Evol Med Dent Sci*. 2016;5(84):6270–5.