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Anatomical and biomechanical parameters relating to migration of the helical blade in proximal femoral fractures fixed by proximal femoral nail anti-rotation

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Abstract
Introduction: Proximal femoral fractures fixation pose dilemma on fixation device to use. Western designed copied proximal femoral nail anti rotation is being used in South-East Asian population extensively. The study aims to study of migration in our population representative of the developing nations.
Methods: 92 patients enrolled in prospective cross-sectional study for 9 months; 89 were evaluated for final migration studies as 3 major complications occurred. The effects of age, fracture, tip-apex distance, quadrant position in femoral head, blade size and length and Neck Shaft angle on migration were analyzed.
Results: There were 42 males and 50 females with the mean age was 68.14 years. At the time of fixation mean Tip Apex Distance was 12.2 mm (7.0mm – 25mm). At 6 months follow-ups, migration occurred in 78.65%. On univariate analysis, there was no effect of fracture pattern on migration (p=0.524). Femoral-Neck shaft angles were fixed in varus in 7, 5 in valgus and 77 within normal range. Relatively higher migration did occur with varus fixation but was not statistically significant (p=0.306). Multivariate analyses were done for nail diameter, nail length, old age and fracture patterns with no statistically significant interactions. The position of helical blade in the quadrant of the femoral head with center-center having minimum migration (p= 0.000). Major complications occurred in 3 patients.
Conclusions: All helical blades do migrate but within acceptable range provided fixation in acceptable Tip Apex Distance. Bone Mineral Density should be kept as co-variable in further studies.

Keywords: Biomechanical, femur, migration, proximal

Introduction
Proximal femoral fractures are global burden adding significant morbidity and mortality. They remain the most frequently operated fracture type in the elderly with the high cost of care [1]. The future incidence of hip fracture worldwide estimated to double to 2.6 million by year 2025, 26% such fractures occurring in Asia and would rise to 37% in 2025 [2]. The largest number of fractures expected to occur in females older than 65 [3].
Myriads of implants have been designed to fix the proximal femoral fractures; however, the dilemma and controversies continue for the proper choice of implant. Although the implant proximal femoral nail anti-rotation has theoretical promising advantage, the challenge continues in South-East Asia to accommodate the design of nail designed according to western population [4, 5]. Our prospective cross-sectional study tries to study on the migration of nail and impact of various factors in our population which might be representative of overall developing nations.

Methods
A prospective cross-sectional study lasted for nine months from 25th September 2018 to 24th June 2019 at BP Koirala Institute of Health Sciences, Dharan, Nepal. Sample size was calculated to be 64 based on proportion of screw migration according to study by Landevoisin *et al.* (2011) [6], which was 16% [6]. However all 92 cases during the study period were analyzed in the study. Ethical approval taken from the institutional review committee and

informed consent were taken from the participants. Ninety-two cases were followed prospectively to analyze the helical blade migration from time of fixation to six months. Proximal femoral fractures above 18 years of ages were included. Pathological fractures, bilateral fractures, fractures in non-ambulatory patients were excluded from the study. Primary objective was to analyze migration in terms of Tip Apex Distance (TAD) calculated from Antero-Posterior and Lateral radiographs (Figures 1, 2).

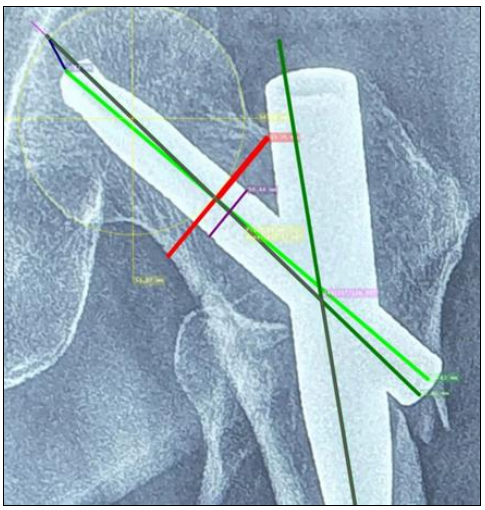

Fig 1: Antero posterior view analysis of plain radiograph

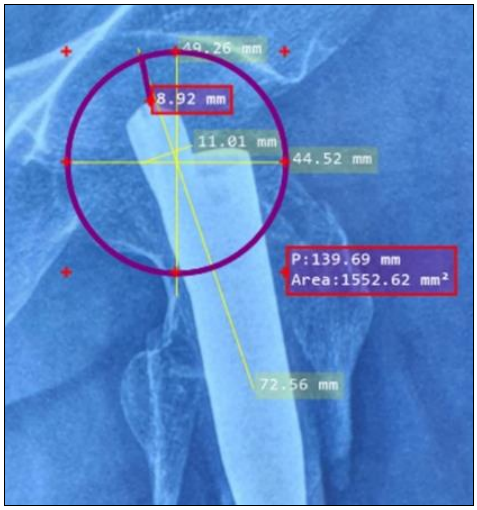

Fig 2: Lateral View Analysis of Plain Radiograph of hip.

Secondary outcome variables were the influence of factors – age, fracture biomechanical pattern, neck-shaft angle, and helical blade position on quadrants of femoral head. To simplify the observation of fracture patterns and avoid inter-observer variations, fracture was classified in three categories (Figure 3)

Descriptive study, independent samples test, univariate and multivariate analyses were performed with statistical package for social sciences (SPSS) version 26. The significant threshold was defined for *p* value <0.05.

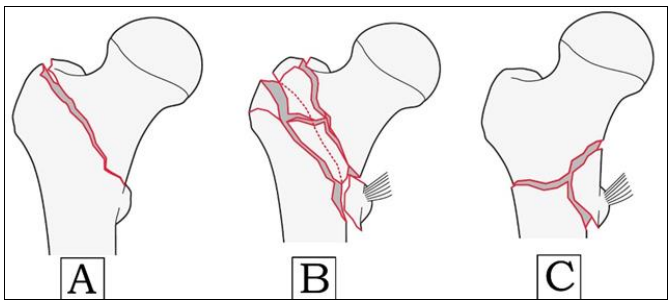

Fig 3: Simplified Classification A) simple intertrochanteric fracture B) Complex fractures that included comminuted and trochanters fractures C) Low Subtrochanteric, Transverse and Reverse fracture pattern.

Results

Ninety-Two patients of proximal femoral fractures were analyzed. There were 42 males and 50 females. Three major complications occurred during the follow-up, so only 89 cases were analyzed for final migration study. The mean age was 68.14 years. Thirty-one patients were less than 65 years and 61 patients were 65 and above. The age category had no statistically significant effect on migration (Table 1).

Table 1: Migration according to age category

	Age category	N	Mean (mm)	Significance
Migration	<65 years	31	1.097	p = 0.146
	>65	58	1.505	

Left side was predominately involved. At the time of fixation mean Tip Apex Distance (TAD) was 12.2 mm, range 7.0mm – 25mm. At 6 months follow-ups, migration occurred in 78.65%. Migration was slightly higher 65 and higher group compared to less than 65 years (mean: 1.505mm vs 1.097) but statistically insignificant (p=0.146). Simple proximal fractures (A) occurred in 45, Complex fractures in 35 and category C fractures occurred in 12. On univariate analysis, there was no effect of fracture pattern on migration (Welch, Brown Forsythe Sig. 0.524, 0.512 respectively). Femoral neck shaft angles were analyzed and found that 7 were fixed in varus, 5 in valgus and 77 within normal range. Relatively higher migration did occur with varus fixation but was not statistically significant (Welch, Brown-Forsythe Sig. 0.306, 0.228 respectively) (Table 2).

The position of helical blade in the quadrant of the femoral head did have effect on migration with center-center having minimum migration with highest with superior anterior placement of helical blade (Welch, Brown-Forsythe Sig. 0.000, 0.000 respectively) (Table 2) (Figure 4).

Table 2: Effects of fracture pattern, Neck-Shaft Angle and position of helical blade on migration

Effect	Parameters	Number	Mean	Significance
Effect of fracture pattern on Migration	Simple (A)	43	0.1479 (cm)	p = 0.524, 0.512*
	Complex (B)	35	0.1326 (cm)	
	Low Subtrochanteric/ Transverse/Reverse (C)	11	0.1027 (cm)	
		89		
Effect of Neck-Shaft Angle fixation	Varus	7	0.2000 (cm)	p= 0.306, 0.228*
	Valgus	5	0.1740 (cm)	
	Normal	77	0.1281 (cm)	
		89		
Effect of Helical blade position in Quadrant	Superior Anterior	21		p=0.0001, 0.0001*

	Superior Center	7	
	Center Anterior	16	
	Center Center	23	
	Center Posterior	3	
	Inferior Posterior	19	
		89	

* Welch, Brown-Forsythe

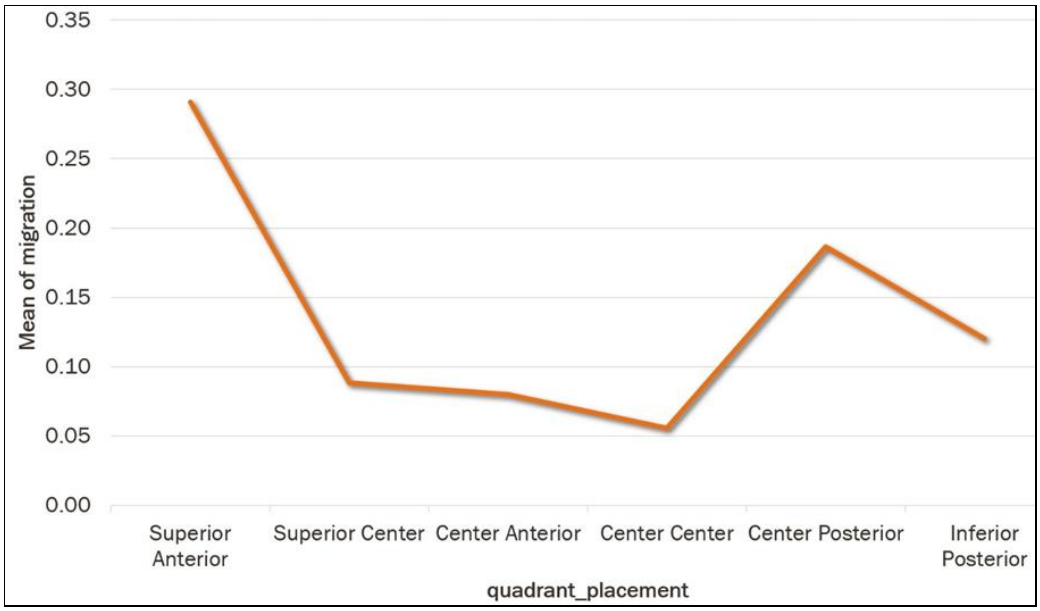

Fig 4: Position of helical blade in femoral head versus mean of migration (in cm)

Multivariate analyses were done for nail diameter, nail length, old age and fracture patterns. There were no statistically significant findings (Table 3).

Table 3: Effect of Multiple Variable Interaction on migration of helical blade

Effect	Parameters	Significance (p)
Effect of nail size on migration	Nail Diameter	0.419
	Nail Length	0.140
	Nail Diameter x Nail Length	0.646
Age and fracture pattern	Age	0.98
	Fracture Pattern	0.452
	Age x Fracture pattern	0.327

Major complications did occur in 3 patients; massive trochanteric wound with exposed implant in one and complete cut out in two. Wound was managed with vacuum assisted closure and secondary closure was possible. One cut out patient was managed with Hemi-Replacement Arthroplasty (Figure *5*) and another denied further surgery.

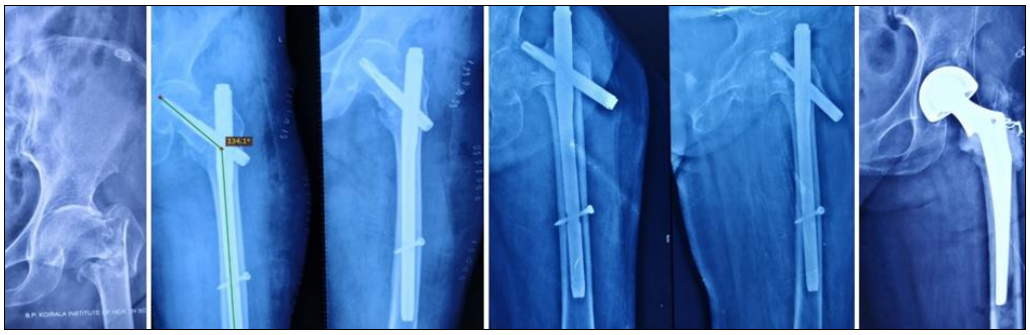

Fig 5: Properly Fixed Intertrochanteric Fracture failure and replaced with Cemented Hemi Replacement Arthroplasty

Discussion

Proximal femoral fractures although cited as fractures of elderly do tend to occur in relatively higher numbers of young age groups too [7]. Our study had nearly 20.7% (n=19) who were 60 and below. Whether it is a new osteoporotic trend or a related to mode of trauma, a detailed study needs to done [2, 8].

Rubio-Avilla *et al.* (2013) [9] reported that patients with Tip Apex Distance (TAD) > 25 mm had a significantly greater risk of cut-out than patients with TAD < 25 mm. Higher cutouts were seen in higher TAD groups (mean difference = 6.54 mm).

(9) We had relatively fewer cutouts as our Tip Apex dance was within 7-25 mm, with mean of 12.2 m. The earlier values given by Baumgaertner *et al.* (1995) [10] although for a dynamic hip screw still holds true to time and for helical blades proven by many biomechanical and clinical studies [10, 11, 12, 13].

Juji Ito *et al.* (2015) [14] retrospectively analyzed excessive post-operative sliding of the short femoral nail in 177 cases of femoral trochanteric fractures. They couldn't find correlation of bone quality with the sliding distance. However they found significant sliding distance of AO/OTA 31-A2 fractures compared to AO-OTA 31-A2 fractures ($p< 0.0001$) [14]. Goffin *et al.* (2013) [15] studied the effect of bone compaction around the helical blade of proximal femoral nail anti-rotation on risk of cut-out. They found in a more osteoporotic femoral head characterized by a density corresponding to 75% of the initial bone density, local bone compaction around the helical blade provides additional bone purchase, thereby decreasing the risk of cut-out and strongly recommended to keep the bone density of the femoral head as covariable in future studies [15].

Correct placement of the helical blade seems to be the primary determining fracture to hold the construct in place. Center-center placement is recommended. All blades to migrate an acceptable distance but do so statistically less in center-center followed by center-inferior placement compared to others [16, 17].

Reduction with slight valgus is greatly described in both sliding hip screw and intramedullary devices. Indeed, the migration can be termed as varus collapse. Valgus fixation as much as 160-170 is good and acceptable; and does provide significant postero-medial contact and closes the gap [12, 18].

More than fracture pattern, implant size and dimensions and old age, what seem to matter most is the quality of bone remaining in the femoral head which is highest in center-center quadrant of the femoral head and to correctly take purchase of the helical blade in the subchondral bone with proper surgical technique [16, 19].

We had 2 major cut-outs in superiorly in helical blades, both in elderly patient. Both has been fixed with Normal Neck-Shaft restoration and within normal range of Tip-Apex distance. However, one had cortices overlapped and properly reduced for maximum contact. Other one had no observable findings. However, bone mineral density studies were not evaluated in this study which might be a significant factor in migration of helical blades.

Conclusions

Migration do occur but within an acceptable range if fixed within acceptable Tip-Apex Distance. Positioning in the center-center quadrant is highly recommended taking a part of calcar if possible. Designs with western dimension and design do work well in our South-East Asian countries too and thus can be safely recommended for use.

Limitations

Our study couldn't incorporate Bone Mineral Density (BMD) as co-variable due to lack of BMD machine which can be incorporated in future studies to further delineate its effect.

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