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Comparison of Proximal Femoral Geometry between Femoral Neck and Intertrochantric Fractures

Nazir K[1]*, Alok T[2], Dirgharaj RC[3], Kapilmani KC[4], Sudeep K[2], Sanjeev A[3] and Milan KC[4]

[1]Department of Orthopedic Surgery, Lumbini Provincial Hospital, Nepal

[2]Department of Orthopedic Surgery, National Trauma Center, Nepal

[3]Department of Orthopedic Surgery, Bharatpur Hospital, Nepal

[4]Department of Orthopedic Surgery, Civil Service Hospital, Nepal

***Corresponding author:** Nazir Khan, Consultant Orthopaedic Surgeon, Department Of Orthopaedic Surgery, Lumbini Provincial Hospital, Butwal, Rupandehi, Nepal, Tel: 977-9851248352; Email: drkhannazir@gmail.com

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Abstract

Background: Intertrochanteric fracture of femur is one of the commonest injuries comprise approximately half of all hip fractures caused by low energy trauma in elderly population and 20% of the operative workload of an orthopedic trauma. There is increasing evidence that the proximal femoral geometry has an important role in the etiology of hip fractures. We performed a simple radiological study to investigate the relationship of proximal femoral geometry between Femoral neck (NOF) and Intertrochanteric (IT) fractures.

Methods: A Prospective Radiographic Observational hospital based clinical study was conducted at Department of Orthopedic Surgery, Lumbini Provincial Hospital, National Trauma Center, Bharatpur Hospital and Civil Service Hospital from January 2021 to July 2022. A total of 120 patients, 60 sustaining Femoral Neck fracture and 60 sustaining Intertrochanteric fracture were enrolled. Proximal femoral geometry (HAL, FNL and NSA) was measured from the contralateral normal hip in the X-ray Anteroposterior view of pelvis. The data were recorded and Student's t test was used to compare the continuous variables.

Results: Statistically significant difference in HAL was found between NOF and IT fractures in age group 51-60 years (11.64 ± 0.05cms vs 11.04+/-0.65cms, p 0.025). However, no statistical difference was found in FNL (2.62+/-0.29cms vs 2.69+/-0.34, p 0.224) and NSA (129.71+/-3.56 degrees vs 129.77+/-3.67 degrees, p 0.92) between two groups.

Conclusion: HAL was found to be increased in group sustaining femoral neck fracture as compared to group with Intertrochanteric fracture, especially in age group 51-60 years. We didn't find any statistical difference in FNL and NSA among these two fracture group. As most of the literature has also stated, we conclude that HAL is an independent predictor of risk of hip fracture and that the patients with increased HAL are more prone to femoral neck fracture. It can be used as a screening tool in patients to predict and thereby forewarn about their susceptibility to hip fracture.

Keywords: Intertrochanteric Fracture; Femoral Neck Fracture; Hip Axis Length; Neck Shaft Angle; Femoral Neck Length

Introduction

Hip fractures are common and comprise 20% of the operative workload of an orthopedic trauma [1]. Life expectancy is increasing worldwide, and these demographic changes can be expected to cause the number of hip fractures occurring worldwide to increase from 1.66 million in 1990 to 6.26 million in 2050 [2]. Hip fractures account for 7% of all adult whole body fractures and 24% in geriatric populations [3]. In 1990, 26% of all hip fractures occurred in Asia, whereas this figure could rise to 37% in 2025 and to 45% in 2050 [4]. Hip fractures are related to high mortality, long term disability, and reduced quality of life, and thus, imposing a heavy burden on the individual, family, society, and health care system [5,6]. Femoral neck fracture and IT fracture are common hip fracture that occur in patient aged 60 years and more [3,7]. The increase in the incidence of femoral neck fractures in the elderly is due to decreased bone mass and bone quality. This results in a decrease in proximal femur strength and the increased occurrence of hip fractures despite low energy injuries [8]. A large number of studies have confirmed that the proximal femoral geometry structure is an important determinant of proximal femoral bone strength [9-11]. Therefore, it is of great significance to study the geometric parameters of the hips of elderly patients with hip fractures. Three of the important parameters of proximal femoral geometry are the Hip Axis Length (HAL), Femoral Neck Length (FNL) and the Neck-Shaft Angle (NSA) [12-14]. HAL is defined as a line extending along the femoral neck axis from the base of greater trochanter to the inner pelvic brim [13]. FNL is defined as the distance between the two perpendicular lines which transects the hip axis length, one at the level of the trochanter, and the other at the level of head flare. Neck-shaft angle is the angle formed by femoral shaft axis and femoral neck. This study analyzes the geometric parameters of proximal femur and finds out the risk factor for Femoral Neck fracture & Femoral Intertrochanteric hip fractures based on radiological parameters. There are various studies suggesting that the geometric parameters of the proximal femur have a relation with the occurrence of hip fractures. For example: One study concluded that Larger FNL is a risk factor for intertrochanteric fracture whereas larger NSA is a risk factor for femoral neck fractures [3], whereas the other study concluded that patient with larger HAL and larger NSA were prone to fracture of neck of femur [15]. So, this study can also analyze the geometric parameters of proximal femur and analyze the risk factor which will have implications for future screening and prevention of such hip fractures. Moreover, we can have the normal anatomical measurements of bones and joints which are important for reference to get satisfactory anatomical and functional restoration of fractures. Furthermore, it can provide guidance for production of individualized implants/ prosthesis of proximal femur.

Materials and Methods

Under ethical approval from institutional review committee (IRC) of National academy of medical sciences (NAMS), a prospective radiographic observational hospital based clinical study was conducted at Department of Orthopedic Surgery, National Trauma Center, Lumbini Provincial Hospital, Bharatpur Hospital and Civil Service Hospital from January 2021 to July 2022.

We used Convenience sampling technique using formula, $N= 2 (Z\alpha+Z\beta) 2\sigma 2 / d2$ to obtain sample size and hence 60 cases each in femoral neck fracture and femoral intertrochanteric fracture group.

All skeletally mature adults with Femoral Neck fracture or Femoral Intertrochanteric fracture were included in study. Patients with bilateral hip fractures, with malignant disease, with pathological fractures, on medication which are known to affect the bone metabolism, age less than 18 years, known case of hypercalcemia or hypocalcemia, with congenital anomalies and the paralytic disorders like polio , with head injury, pneumothorax or hemothorax, pelvic fractures or the fractures involving the skeletal extremities were excluded from study.

Now all the remaining patients who were screened out were considered for the rest of the study. These patients were subjected to digital X-ray pelvis with both hips. While taking the X-rays, the patient was kept in supine position with traction in the involved limb with their arms adducted and their forearm over the chest. Digital X-ray of pelvis with bilateral hip anteroposterior view were taken in traction and internal rotation of 15 degrees of the uninvolved limb.

Figure 1: Positioning of the Patient.

Once the film had been taken, measurements of HAL, FNL, NSA from contralateral normal side was taken via the "CARESTREAM image suite" software preinstalled in hospital radiology department. In every patient's Xray the radiological ID provided by the Department had been noted. All these measurements were made from the contralateral uninvolved sound hip joint.

The hip axis length is the distance between the lateral edge of the trochanter and the inner table of the pelvis which was measured in centimeters. On drawing the line through the software, equal distance between the axis of neck and either side of the neck was maintained.

Figure 2: Measuring HAL in "CARESTREAM image suite" software.

The NSA measured by means of drawing a line along the anatomical axis of the femur and a line passing through the axis of neck. It was measured in degrees.

Figure 3: Measurement of NSA from "CARESTREAM image suite" software.

FNL is a component of HAL and it is measured from the medial flare i.e., an imaginary line connecting from the superior border of lesser trochanter to greater trochanter medial aspect to the flare of femoral head.

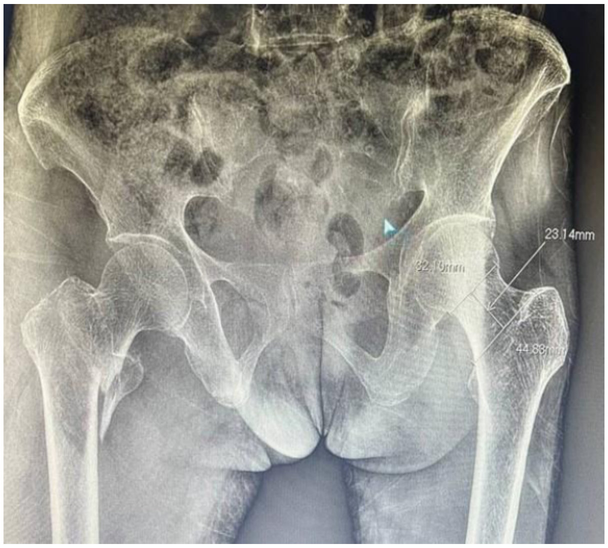

Figure 4: Measurement of FNL from "CARESTREAM image suite" software.

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 23 for Windows. Continuous variables were expressed in Mean +/- Standard deviation. Student's t-test was used to compare the continuous variables between patients with femoral neck fractures and patients with femoral intertrochanteric fractures. Categorical values were expressed in numbers and percentage. Chi-square test was used for categorical variables. Overall significance level was maintained at 'p' value <0.05.

Results

The study cohort consists of 120 cases, 60 each in femoral neck group and femoral intertrochanteric fracture group. Comparison of the pretreatment baseline data are shown in Tables 1-6.

Baseline data	Femoral neck group (n=60)	Intertrochanteric group (n=60)
Gender(Male/Female)	**26/34**	**27/33**
Mechanism of injury		
Fall from standing height	54	56
Fall from bed	4	3
RTA	2	1
Age group		
<50	9	3
51-60	12	10
61-70	24	19
>70	15	28

Table 1: Pre-treatment baseline data.

Test of HAL between IT & NOF

Group	N	Mean	SD	P-value	Results
HAL in IT Centimeter (cm)	60	11.195	1.143	0.668	Not significant
NOF	60	11.273	0.823		

Table 2: Group statistics of HAL**.**

Group	N	Mean	SD	P-value	Results
HAL in IT Centimeter (cm)	3	11.855	0.0176	0.890	Not significant
NOF	9	11.917	0.7414		

Table 3: Test of HAL between NOF & IT in age <50 years.

Group	N	Mean	SD	P-value	Results
HAL in IT Centimeter (cm)	10	11.047	0.6577	0.025	Significant
NOF	12	11.645	0.4994		

Table 4: Test of HAL between NOF & IT in age 51-60 years.

Group	N	Mean	SD	P-value	Results
HAL in IT Centimeter (cm)	15	10.92	0.627	0.502	Not significant
NOF	28	11.1529	1.244		

Table 5: Test of HAL between NOF & IT in age 61-70 years.

Group	N	Mean	SD	P-value	Results
HAL in IT Centimeter (cm)	19	11.2308	1.287	0.627	Not significant
NOF	24	11.0667	0.9097		

Table 6: Test of HAL between NOF & IT in age >70 years.

Hip Axis Length (HAL), among the age group of 51-60 years, IT group had mean of 11.0470 cm and SD of 0.6577, whereas NOF group had mean of 11.645 cm and SD of 0.4994 with p value of 0.025, suggesting that patients with NOF fracture had higher HAL [16]. This signifies that HAL is statistically different between two groups in the age group of 51-60 years (Tables 7-11).

Test of FNL between IT & NOF

Group	N	Mean	SD	P-value	Results
FNL in IT Centimeter (cm)	60	2.932	0.3445	0.244	Not significant
NOF	60	2.6247	0.2945		

Table 7: Group statistics.

Group	N	Mean	SD	P-value	Results
FNL in IT Centimeter (cm)	3	2.5667	0.215	0.465	Not significant
NOF	9	2.7103	0.2985		

Table 8: Test of FNL between NOF & IT in age <50 years.

Group	N	Mean	SD	P-value	Results
FNL in IT Centimeter (cm)	10	2.626	0.2593	0.499	Not significant
NOF	12	2.7092	0.2995		

Table 9: Test of FNL between NOF & IT in age 51-60 years.

Group	N	Mean	SD	P-value	Results
FNL in IT Centimeter (cm)	19	2.7314	0.4113	0.285	Not significant
NOF	24	2.6079	0.3359		

Table 10: Test of FNL between NOF & IT in age 61-70years.

Group	N	Mean	SD	P-value	Results
FNL in IT Centimeter (cm)	15	2.5325	0.1961	0.131	Not significant
NOF	28	2.6823	0.3472		

Table 11: Test of FNL between NOF & IT in age >70 years.

The mean FNL for NOF fracture group was 2.62 cm with standard deviation of 0.29cm and for IT fracture group was 2.69 cm with standard deviation of 0.34 cm (p value of 0.24). The insignificant p value in group statistics as well as in various age groups suggests that there is no significant difference in FNL between two fracture groups [17]. Although FNL is a part of HAL, we could not relate this significance from our observation (Tables 12-16).

Test of NSA between IT & NOF

Group	N	Mean	SD	P-value	Results
NSA in degree IT	60	129.7725	3.6745	0.929	Not significant
NOF	60	129.7133	3.5653		

Table 12: Group statistics of NSA.

Group	N	Mean	SD	P-value	Results
NSA in degree IT	3	132.133	3.971	0.551	Not significant
NOF	9	130.333	4.468		

Table 13: Test of NSA between NOF & IT in age <50 years.

Group	N	Mean	SD	P-value	Results
NSA in degree IT	10	128.22	3.17	0.908	Not Significant
NOF	12	128.383	3.351		

Table 14: Test of NSA between NOF & IT in age 51-60 years.

Group	N	Mean	SD	P-value	Results
NSA in degree IT	19	129.2711	3.36	0.498	Not significant
NOF	24	129.983	3.416		

Table 15: Test of NSA between NOF & IT in age 61-70 years.

Group	N	Mean	SD	P-value	Results
NSA in degree IT	15	129.973	3.492	0.717	Not significant
NOF	28	130.414	3.916		

Table 16: Test of NSA between NOF & IT in age >70 years.

Discussion

Geometry of proximal femur has been shown to be important for the evaluation of risk of fractures in literature. The mechanical properties of bone at tissue level are determined by structure of the bone and quality of the bone [18,19]. It is necessary to evaluate the structural anatomy of the bone to predict the fracture pattern and incidence. It has been well established that a significant role is played by the geometrical configuration and the bio-material characteristics in providing strength to a structure. To evaluate a fracture completely it is mandatory to evaluate the construct of the bone in terms of the geometry as well as the material the bone is made of. The calcified matrix within the bone determine the bone density [20-22]. In selecting the parameters, we regarded the proximal femur as a cantilever and assumed that the angle, length and diameters are of most importance in determining fracture patterns [23]. Of these, HAL, FNL and NSA were considered to be the most reliable measures to be determined in our study. With large sample size in our study we tried to find out the mean values for these three different radiological parameters for both fracture types and tried to find if there is a significance for all these parameters with a specific type of fracture [24].

Based on gender, females were the higher (57%) in both the NOF and IT fracture group. This is supported in a study by Patel AJ, et al. [25] (62% females), Hu ZS, et al. [26] Hu ZS, et al. [3] (77% females) and Pulkkinen P, et al. [27] (74% females). This suggests the fact that hip fractures are more common in female as compared to male. Post menopausal osteopenia could be the reason for its high occurrence in females.

We observed that fall injury was the major mode of injury in both the fracture groups (96.66% in NOF, 98.33% in IT). Majority of these patients were in the age group <50 years. Similar to our study, Hu ZS, et al. [3] and Patel AJ, et al. [25] also observed similar findings regarding the mode of injury.

There exists very limited evidence, regarding the relationship between age and various hip geometry parameters. The ability of a bone to resist a fracture depends on the amount of bone, spatial distribution of bone mass (micro architecture anatomy) and the intrinsic properties of materials forming the bone [28]. In our study, there exists no correlation between the age and NSA/FNL in fractured hips regardless of the type of fracture. Thus, the age-related changes typically occur mostly in the internal structure of bone and not in the gross anatomy of proximal femur.

Regarding the HAL, there was a statistically significant difference between NOF and IT fracture group. The patients with NOF fracture in the age group of 51-60 years had larger HAL as compared to patients with IT fracture group. Our findings was similar to study conducted by Patron, et al. [29] in 2006, Deboeuf, et al. [30] in 2006 and Giovanni, et al. [31] in 2016.

However the study by Patel AJ, et al. [25] in 2021 and Gnudi S, et al. [14] in 2002 suggests otherwise. They have conclude that HAL in IT fracture was significantly higher than NOF fracture which is contradictory to our result. Few studies done by Hu ZS, et al. [3] in 2018, Han J, et al. [32] in 2016, Li Y, et al. [33] in 2016 suggests that there is no significant difference in HAL in two groups.

The significance in p value (Table 17) suggests that there exists an association between the hip fractures and the geometrical structure. HAL had been shown to predict the hip fractures independent of age and BMD [34]. As each SD increase in HAL is associated with 1.8 times the risk of hip fractures [35], this effect is being independent of the bone mass.

	IT	NOF	P value
My study	11.04 +/- 0.65	11.64 +/- 0.49	0.025
Patron et al	12.74 +/- 0.81	13.2 +/- 0.81	0.021
Giovanni et al	10.09 +/- 0.63	10.67 +/- 0.74	0.001
Debouf et al	9.25	9.42	0.03
Amit et al	12.51 +/- 1.05	11.98 +/- 0.99	0.04
Gnudi et al	10.7 +/- 0.6	10.09 +/- 0.7	0.01
Zu Sheng et al	11.99 +/- 1.02	11.82 +/- 0.87	0.2
Jun Han et al	10.18 +/- 0.6	10.1 +/- 0.57	0.65
Yizhang et al	10.19 +/- 0.6	10.22 +/-0 0.59	0.91

Table 17: HAL comparison to other studies.

We observed no statistical significance difference in NSA between the two groups, similar to compared to studies done by Patel AJ, et al. [25] and Michelotti J, et al. [36]. NSA was found to be significantly higher in patients with NOF fractures than IT fractures in a study done by Partanen J, et al. [37]. His study consists of Sievanen H, et al. [38] NOF and 24 IT fractures. Similarly study by Hu ZS, et al. [3] consisting of 101 NOF fractures and 98 IT fractures also showed no significant difference in NSA between two groups, which was similar to our study. A wider NSA was detected by Gnudi S, et al. [14] in a cross sectional study involving 88 NOF and 93 IT fractures involving menopausal women over 69 years of age. But unlike our study, all the measurements were taken from DEXA scan, yet the reason for the differences in NSA between two groups could not be explained [14].

	IT	NOF	P value
My study	129.77 +/- 3.67	129.71 +/- 3.5	0.92
Partanen et al	130.03	135.7	<0.05
Gnudi et al	132.7 +/- 5.7	136.3 +/- 5.6	0.001
Zu Sheng et al	132.07 +/- 4.17	137.63 +/- 4.6	<0.001

Table 18: Comparison of NSA with other studies.

FNL in our study showed no significant differences between two groups which was similar to study by Partanen J, et al. [37] and Michelotti J, et al. [36]. However study done by Hu ZS, et al. [3], Patron M, et al. [29] and Patel AJ, et al. [25] showed significant differences in FNL between two groups, as shown in Table 19.

	IT	NOF	P value
My study	2.69 +/- 0.29	2.62 +/- 0.29	0.244
Zu Sheng et al	10.35 +/- 0.83	9.93 +/- 0.79	<0.001
Patron et al	2.77 +/- 0.4	3.24 +/- 0.41	0.014
Amit et al	10.64 +/- 0.89	10.05 +/- 0.72	0.007

Table 19: Comparison of FNL with other studies.

FNL just like other proximal femoral dimensions highly depends on height of the individual. Bergot C, et al. [39] also observed that the FNL was independent of age as in our material although we did not measure the height of the patients at all.

Thus, from our study we were not able to detect any difference between the NOF and IT fractures by means of the parameters i.e., NSA, FNL. So, the difference in the mechanism between the femoral neck and trochanteric fractures were not confirmed in our study, by means of these two parameters alone.

In one of the studies by Pulkinnen P, et al. [27], with 114 post-menopausal women, (49 NOF, 25 IT fractures and 40 controls), the combination of NSA with more geometrical parameters along with BMD improved the accuracy in assessing the fracture type. Here NSA was found to be elevated in NOF fractures than in controls, but there was no major difference in the trochanteric group compared with the controls [27]. As in our study, there was no significant difference between NOF and IT fractures by means of FNL measurements. But this study differs from ours in way it has been carried out by means of including controls, whereas in our study there are no controls i.e., only the patients have participated in the study with no normal subjects.

In general, age related changes in bone geometry attempt to preserve the strength of bone as a whole [28]. There is another study by Sievannen H, et al. [38], who suggested that, there have been remarkable alterations in the proximal femur macro anatomy within past 1000 years. In their study, they compared the medieval hip anatomy with contemporary hip anatomy and they suggested that femoral neck axis has become larger and its cross section has become proportionately smaller and oval shaped. All these changes remarkably increase the risk of hip fractures especially when osteoporosis co exists. Although FNL is a component of HAL, its role in prediction of risks of hip fractures is not clear. HAL measurements increases on adduction of hip because of inner shape of pelvis Michelotti J, et al. [36], which should be avoided by means of standardization of the position of patient on subjecting to X ray.

Conclusion

Hip Axis Length (HAL) is significantly increased in the femoral neck fractures in comparison with intertrochanteric fractures [40-42]. As most of the literature says Hip Axis Length (HAL) had been an independent risk factor positively associated with hip fracture risk and thus increased in patients with femoral neck fractures [43]. It can be used as a clinically useful screening tool for evaluation of patients with hip fracture risk and to predict and thereby forewarn about their susceptibility to hip fractures. There is no significant difference in FNL and NSA between two groups [44].

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