Does Proximal Hip Geometry Affect Fracture Type in The Elderly Population?

Emrah Sayit

Samsun Education and Research Hospital: Samsun Egitim ve Arastirma Hastanesi

Nizametin Guzel

Samsun Education and Research Hospital: Samsun Egitim ve Arastirma Hastanesi

Asli Tanrivermis Sayit (✉ draslitanrivermissayit@gmail.com)

Ondokuz Mayis University Faculty of Medicine: Ondokuz Mayis Universitesi Tip Fakultesi

<https://orcid.org/0000-0003-2861-156X>

Research Article

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Abstract

Background

The aim of this study was to determine the differences in proximal femoral geometric (PFG) parameters between patients with femoral neck fractures(FNFs) and patients with intertrochanteric fractures (ITFs).

Methods

We retrospectively evaluated 114 patients (33 FNFs, 81 ITFs.) who were hospitalized secondary to hip fractures. Patients were divided into two groups: patients with FNFs and patients with ITFs. The PFG parameters (the neck shaft angle, center-edge angle, femoral head diameter, femoral neck diameter, neck/head ratio, femoral neck axial length, femoral shaft diameter, hip axial length, and neck/hip length ratio) were measured on the hip joint radiographs.

Results

There were no statistically significant differences in age and gender between the FNF and ITF groups. In addition, there were no statistically significant differences in the PFG parameters between the FNF and ITF groups except in the neck/hip length ratio (NHLR) (0.86 ± 0.03 vs 0.84 ± 0.03 , $p = 0.05$). When a 3-way multivariate analysis was performed according to gender, fracture type, and fracture site, the femoral head diameter, femoral neck diameter, femoral neck axial length, femoral shaft diameter, hip axial length, and NHLR were found to be greater in females than in males, and a statistically significant relationship was found between gender and these variables.

Conclusion

Only the NHLR was significantly higher in the ITF group, so this study revealed that a higher NHLR, which is the presence of a longer hip axis combined with a shorter neck axis, is a risk factor for ITF after a minor trauma.

Introduction

Hip fractures are the most serious complication of osteoporosis and are increasing annually in the elderly population. Despite advanced orthopedic treatment options, the morbidity and mortality of hip fractures remains high [1]. Hip fractures account for 7% of all body fractures in adults and 24% of elderly fractures [2,3]. The most common types of hip fractures in patients over 65 years of age are intracapsular femoral neck fractures (FNFs) and extracapsular intertrochanteric fractures (ITFs) [4]. The etiology, risk factors, characteristics, and treatment modalities of these two fracture types differ [1].

Although hip fractures due to osteoporosis are frequently seen in the elderly population, they can be seen at any age when a force exceeds the strength of the bone due to decreased bone mass and quality. A decrease in proximal femur strength increases the incidence of hip fractures in low-energy trauma and falls, especially in the elderly population [5]. In order to prevent osteoporotic hip fractures, it is crucial to know the various environmental and genetic factors that may contribute to fractures. The most commonly used method is measuring the bone mineral density (BMD) of various bones, which is useful for determining the risk of developing osteoporotic fractures [6]. Proximal femoral geometric (PFG) parameters are independent parameters that can be used to evaluate the structure of bones, such as their shape and size, and they can be used to determine the risk factors, such as low BMD, for developing osteoporotic fractures [6]. Previous reports have demonstrated associations between hip geometry and hip fracture risk in patients, especially elderly patients and postmenopausal women [7–10]. Although there is some disagreement, the hip axis length (HAL) and neck-shaft angle (NSA) have been shown to be increased in osteoporotic hip fractures [11–15]. While several studies have focused on the relationship between PFG parameters and hip fractures, there is a limited number of studies investigating the relationship between PFG parameters and hip fracture types.

The aim of this study was to determine the differences in PFG parameters between FNFs and ITFs in elderly patients. Furthermore, we attempted to identify why some patients with similar age and bone quality who suffer from low-energy trauma have FNFs and some have ITFs.

Methods

Ethical approval

This retrospective study was conducted in accordance with the Declaration of Helsinki and was approved by our hospital's institutional review board. Informed consent was obtained from all patients prior to surgery.

Patients

From January 2018 to December 2018, 114 patients over 65 years of age who were admitted to the hospital with unilateral hip fractures after minor traumas, such as falls from a standing position or while walking, were included in the study. Of the 114 patients, 39 were male, and 75 were female with a mean age of 80.03 ± 7.73 years and 82.12 ± 7.28 years, respectively. The inclusion criteria were as follows: (1) age older than 65 years; (2) FNFs and ITFs; (3) unilateral fractures; (4) hip fractures caused by minor trauma; and (5) X-ray films of the pelvis and proximal femur before and after operation with standard posture and sufficient quality. Patients with secondary fractures of the same hip; bilateral hip fractures; multiple fractures; pathological fractures; primary and secondary bone tumors; chemotherapy; radiotherapy; Paget's disease; congenital dysplasia; and deformity of the femur and pelvis were excluded from the study. The medical records of the included patients were reviewed for characteristics such as age, gender, and the site of fracture using the hospital's electronic medical record.

Radiographic imaging and analysis

The digital imaging and communication medicine (DICOM) files were retrieved from the picture archiving and communication system (PACS) and transferred to the workstation for review; all measurements were performed digitally by an experienced orthopedic surgeon. The standard radiographic view for the pelvis was obtained in the anterior-posterior (AP) direction with the patient in the supine position. Patients with incorrect positions and inadequate diagnostic information were excluded. The PFG parameters were measured from the normal side due to the broken anatomy of the fractured hip. Any asymmetric hips were not included in the study. The PFG parameters were measured for all fractures using a RadiAnt DICOM viewer on pelvic radiographs. The NSA, center-edge angle (CEA), femoral head diameter (FHD), femoral neck diameter (FND), femoral neck axial length (FNAL), femoral shaft diameter (FSD), and HAL were examined from the AP pelvic radiography as described in the literature (16). The NSA is the angle between the derived axes of the femoral neck and shaft. The CEA is the angle between the midline of the femoral head to the outer edge of the acetabulum and the line through the vertical line of the femoral head. The FHD is defined as the maximum distance from the outer superior edge to the inner and inferior edge of the femoral head. The FND is the maximum distance from the superior to the inferior end of the femoral neck. The FNAL is defined as the junction of the lateral cortex of the femur and the apex of the femoral head with the anatomical axis of the femoral head and neck. The HAL is the distance from the greater trochanter to the inner pelvic brim with the anatomical axis of the femoral head and neck (Figure 1,2).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics, ver. 23 (IBM Corporation, Armonk, NY, USA). To compare the two independent groups, the Student t-test was used. The Chi-Square test was used to test categorical variables. A multivariate analysis of variance (MANOVA) was used to evaluate the influence of the PFG parameters on gender and fracture type and site. The data are expressed as mean $\pm$ standard deviation (SD) and median (minimum–maximum). A p-value equal to or less than 0.05 was considered statistically significant. The relative technical error of measurement (rTEM) method was used for the agreement between observations. According to the analysis results, the rTEM value was 2.58, and the reliability value was 92.1%, which showed that intraobserver compliance was quite high.

Results

Of the 114 patients, 33 had FNFs (mean age: 80.48 ± 7.57 years), and 81 had ITFs (mean age: 81.78 ± 7.44 years). Of the 33 patients with FNFs, 13 (39.4%) were male (mean age: 80.69 ± 7.18 years), and 20 (60.6%) were female (mean age: 80.35 ± 7.99 years). Of the 81 patients with ITFs, 26 (32.1%) were male (mean age: 79.69 ± 8.11 years), and 55 (67.9%) were female (mean age: 82.76 ± 6.97 years). There were no statistically significant differences in age and gender between the FNF and ITF groups ($p=0.40$ and $p=0.59$, respectively).

The PFG parameters of the hips of patients with FNFs and ITFs are shown in Table 1. The FNF group had larger NSAs, smaller CEAs, larger FHDs and FNDs, smaller FSDs, and greater FNALs and HALs compared to the ITF group. The FNF group had smaller NHRs, NHLR, and FSDs compared to the ITF group. There were no statistically significant differences in the PFG parameters between the FNF and ITF groups except in the NHLR (0.86 ± 0.03 vs 0.84 ± 0.03 , $p=0.05$).

The results of the multivariate analysis of the PFG parameters are shown in Table 2. Male patients had larger FHDs (58.7 ± 3.9 vs 52.1 ± 3.7 mm), FNDs (42.2 ± 4.5 vs 37.1 ± 4.3 mm), and FSDs (34.4 ± 2.9 vs 32 ± 3.1 mm) and greater HALs (132.4 ± 12.4 vs 114.4 ± 8.6 mm) and FNALs (110.3 ± 10.4 vs 98.7 ± 7.6 mm) compared to female patients. There was a significant difference in the PFG parameters between genders. Females had larger CEAs ($39.22 \pm 7.11^\circ$ vs $37.52 \pm 6.24^\circ$) and NHLRs (0.86 ± 0.02 vs 0.83 ± 0.02) compared to male patients. There was a significant difference in the CEA between genders. The NSAs in the male and female patients were $139.58 \pm 9.86^\circ$ and $139.79 \pm 8.22^\circ$, respectively, and did not significantly differ. The NHRs in the male and female patients were 0.72 ± 0.06 and 0.71 ± 0.11 , respectively, and did not significantly differ between genders. There were no statistically significant differences in fracture type interactions with gender, fracture site interactions with gender, or fracture type interactions with the fracture site. In addition, there were no statistically significant gender interactions with fracture type and site.

Discussion

Osteoporotic hip fractures include FNFs and ITFs, and these fractures are extremely common in the elderly population [10]. However, many differences have been reported between FNFs and ITFs, such as etiology, risk factors, and patient characteristics [1]. Pulkkinen et al. [17] reported that FNFs predominate at the lowest structural mechanical strength levels, whereas ITFs are more common at high failure loads, and females are more prone to FNFs than males. Recent studies revealed that the PFG parameters can show the susceptibility to hip fractures independent of BMD [5]. But, here, there were no statistically significant differences in age and gender between the FNF and ITF groups ($p=0.40$ and $p=0.59$, respectively).

Lee et al. [5] analyzed the PFG parameters among 16 premenopausal women with minimal-trauma hip fractures and 80 age- and body mass index-adjusted controls. They revealed that a long hip axis and narrow NSA significantly increased fracture risk in a multiple logistic regression analysis using only the PFG parameters. They revealed that the HAL and NSA were BMD-independent predictors of hip fracture and hip geometry might be clinically useful for the identification of patients for whom active fracture prevention should be considered [5]. Han et al. [10] evaluated 197 women aged 65 years or older who had an osteoporotic hip fracture (FNF, 84 patients; ITF, 113 patients). A total of 551 women who visited the hospital to be tested for osteoporosis were included in the control group. The researchers measured the femur BMD and PFG parameters for all subjects and compared them between the control and fracture groups. They reported that there were no significant differences in the HAL and NSA between the control group and the fracture group. In our study, there were no significant differences between the FNF and ITF

groups according to the HAL and NSA in the multivariate analysis, so our study revealed no significant relationship between the HAL or NSA and hip fracture type.

Hu et al. [4] reported that the mean HAL of 101 patients with FNFs was 118.23 ± 8.73 mm, and the HAL of 97 patients with ITFs was 119.97 ± 10.29 mm. In our study, the mean HAL of 33 patients with FNFs was 123.5 ± 14.9 mm, and the HAL of 81 patients with ITFs was 119.3 ± 12.3 mm, but there were no statistically significant differences. We found that the hip axis was longer in the FNF group than in the ITF group, which contrasts the results from the study by Hu et al [4].

Hu et al. [4] found that the mean NSA of the 101 patients with FNFs was $137.63 \pm 4.56^\circ$, and the mean NSA of the 97 patients with ITFs of the femur was $132.07 \pm 4.17^\circ$, which was significantly different. They suggested that a greater NSA was a risk factor for FNF [4]. In our study, the mean NSA of 33 patients with FNFs was $140.12 \pm 7.83^\circ$, and the NSA of 81 patients with ITFs of the femur was $139.55 \pm 9.17^\circ$, but there were no statistically significant differences between fracture type.

Han et al. [10] showed that femoral neck length (FNL) was significantly greater in the control group than in the FNF group ($P < 0.001$). However, there were no statistically significant differences in the FNL between the control group and the ITF group ($P = 0.722$). In addition, they reported that the FNL between both fracture groups was significantly shorter in the FNF group than in the ITF and control groups [10]. Lu et al. [18] reported that the FNAL of patients with ITFs of the femur was 90.68 mm, which was greater than that of the FNF group (88.64 mm). From the biomechanical point of view, the longer axis of the femoral neck causes the greater trochanter of the femur to protrude more, and thus, the possibility of ITF increases when an external force impacts the femoral trochanter. The long axis of the femoral neck and the high risk of proximal femoral fractures have been defined by most scholars [18]. The FNAL has an important role in internal fixation of the proximal femoral fracture and hip arthroplasty. Therefore, restoration of the normal FNAL prior to fracture has important clinical significance for accurate restoration of the normal hip geometric parameters and can improve hip function. In our study, the FNAL was longer in patients with femoral neck fractures (104.1 ± 11.1 mm) than in patients with ITFs (102 ± 9.9), but there were no statistically significant differences between fracture type.

Han et al. [10] revealed that the femoral neck width (FNW) in the control group was significantly smaller than that in the FNF and ITF groups. However, we found no significant differences in the FNAL and FND between the two groups in our study. They reported that after adjusting for age, weight, and height, the odds ratio (OR) for fractures in the FNF group increased depending on a decrease in the FNAL, cross-sectional area (CSA), and femur BMD and an increase in the FNW. Furthermore, they revealed that the OR for fractures increased depending on a decrease in the CSA in the femoral neck and femur BMD and an increase in the FNW in the ITF group [10]. They suggested that an increase in the FNW might be a PFG parameter that plays a significant role as a risk factor for fracture independent of BMD.

Hu et al. [4] evaluated 198 elderly patients over 65 years of age with hip fractures (FNF, 101 patients; ITF, 97 patients). They reported that the CEA were higher in men than in women. Also, they revealed that there

was no statistically significant difference in CEA between the gender, but greater CEA was the risk factor for ITFs. In here, CEA was larger in woman than in men and CEA was greater in ITF group than in the FNF group, compatible with the literature.

Hu et al. [4] showed statistically significant differences in the NSA between the FNF group and the ITF group. They revealed that a greater NSA was a risk factor for FNF. In our study, the FNF group had a greater NSA when compared to the ITF group, compatible with the literature. Also, they revealed that FND is greater in FNF group than the ITF group, with a statistically significant difference [4]. They claimed that greater FND was a protective factor for the ITF group. In our study, FND was greater in the FNF group than the ITF group, without statistically significant difference.

In our study, the FNF group had larger NSAs, smaller CEAs, larger FHDs and FNDs, smaller FSDs, and greater FNALs and HALs compared to the ITF group. The FNF group had smaller NHRs, NHLR, and FSDs compared to the ITF group. There were no statistically significant differences in the PFG parameters between the FNF and ITF groups except in the NHLR (0.86 ± 0.03 vs 0.84 ± 0.03 , $p=0.05$).

The limitation of this retrospective study is because of not having height, weight and BMI of the patients, the measurements could not be normalized.

In conclusion, we evaluated the differences in geometric morphological parameters of the proximal femur in different hip fracture types and gender. Only the NHLR was significantly higher in the ITF group, so this study revealed that a higher NHLR, which is the presence of a longer hip axis combined with a shorter neck axis, is a risk factor for ITF after a minor trauma.

List Of Abbreviations

PFG

Proximal femoral geometric

FNF

Femoral neck fractures

ITF

Intertrochanteric fractures

NHLR

Neck/hip length ratio

BMD

Bone mineral density

HAL

Hip axis length

NSA

Neck-shaft angle

DICOM

Digital imaging and communication medicine

PACS

Picture archiving and communication system

AP

Anterior-posterior

CEA

Center-edge angle

FHD

Femoral head diameter

FND

Femoral neck diameter

FNAL

Femoral neck axial length

FSD

Femoral shaft diameter

MANOVA

Multivariate analysis of variance

SD

Standard deviation

rTEM

Relative technical error of measurement

FNL

Femoral neck length

FNW

Femoral neck width

OR

Odds ratio

CSA

Cross-sectional area

FT

Fracture Type

FS

Fracture Site

Declarations

Funding: No organization sponsored the research.

Availability of data and materials: All the data will be available upon motivated request to the corresponding author of the present paper.

Ethics approval and consent to participate: This study was approved by the institutional review board (approval no. TUEK 37-2019 BADK/8-64) of the Samsun Education and Research Hospital.

Patient consent for publication: Informed consent was obtained from all patients prior to surgery.

Competing interests: The authors declare that they have no competing interests.

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Tables

Table 1
Proximal femoral geometric parameters of the hips in patients with femoral neck fractures and intertrochanteric fractures.

	FNF (n = 33)	ITF (n = 81)	p
Neck-Shaft Angle (°)	140.12 ± 7.83	139.55 ± 9.17	0.75
Center-Edge Angle (°)	37.34 ± 5.66	39.16 ± 7.24	0.19
Femoral Head Diameter (mm)	55.4 ± 5.2	54 ± 4.7	0.15
Femoral Neck Diameter (mm)	39.2 ± 5	38.7 ± 5	0.63
Neck/Head Ratio	0.71 ± 0.06	0.72 ± 0.11	0.53
Femoral Neck Axial Length (mm)	104.1 ± 11.1	102 ± 9.9	0.32
Femoral Shaft Diameter (mm)	32.7 ± 2.9	32.9 ± 3.4	0.83
Hip Axial Length (mm)	123.5 ± 14.9	119.3 ± 12.3	0.12
Neck/Hip Length Ratio	0.84 ± 0.03	0.86 ± 0.03	0.05
FNF: Femoral neck fracture, ITF: Intertrochanteric fracture			

Table 2
Multivariate analysis of proximal geometric parameters

	Gender	FT	FS	Gender*FT	Gender*FS	FT*FS	Gender*FT*FS
Neck-Shaft Angle	0.77	0.76	0.53	0.85	0.96	0.50	0.62
Center-Edge Angle	0,44	0.47	0.28	0.26	0.12	0.50	0.75
Femoral Head Diameter	0.00	0.12	0.61	0.10	0.25	0.51	0.41
Femoral Neck Diameter	0.00	0.67	0.08	0.09	0.58	0.57	0.81
Neck/Head Ratio	0.56	0.60	0.27	0.51	0.91	0.81	0.52
Femoral Neck Axial Length	0.00	0.35	0.11	0.13	0.47	0.72	0.39
Femoral Shaft Diameter	0.00	0.28	0.08	0.71	0.78	0.69	0.66
Hip Axial Length	0.00	0.10	0.24	0.08	0.27	0.99	0.55
Neck/Hip Length Ratio	0.00	0.05	0.17	0.61	0.27	0.28	0.38
FT: Fracture Type, FS: Fracture Site (Left/ Right)							

Figures

Figure 1

1a: The parameters of proximal femoral geometry demonstrated on the hip X-ray 1b: The parameters of proximal femoral geometry demonstrated on the hip X-ray