EVALUATION OF PROXIMAL FEMUR GEOMETRY ON PLAIN RADIOGRAPHS AMONG DIFFERENT ETHNIC GROUPS

BY

DR. SANEED KHALIQ
MBBS

A thesis presented to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of Master of Philosophy in Anatomy

DEPARTMENT OF ANATOMY
BAHRIA UNIVERSITY MEDICAL & DENTAL COLLEGE

JULY, 2021

BAHRIA UNIVERSITY ISLAMABAD

APPROVAL SHEET

SUBMISSION OF HIGHER RESEARCH DEGREE THESIS

Candidate's Name: Dr. Saneed Khaliq

Discipline: Anatomy

Faculty/Department: Anatomy

I hereby certify that the above candidate's work including the thesis has been completed to my satisfaction and that the thesis is in a format of an editorial standard recognized by the faculty/ department as appropriate for examination.

Signature: ________________________________

Principal Supervisor: Prof. Dr. Aisha Qamar

Date: ____________________________________

The undersigned signifies that:

1. The candidate presented at a pre-completion seminar, an overview and synthesis of major findings of the thesis, and that the research is of a standard and extent appropriate for submission as a thesis.

2. I have checked the candidate's thesis and its scope, format and editorial standards are recognized by the faculty / department as appropriate.

Signature: _____________________________________

Head of Department: Prof. Dr. AmbreenUsmani

Date: ____

AUTHOR'S DECLARATION

I, Dr. Saneed Khaliq hereby state that my M.Phil. thesis titled "Evaluation of proximal femur geometry on plain radiographs among different ethnic groups" is my own work and has not been submitted previously by me for taking any degree from this university, the **Bahria University** or anywhere else in the country/world.

At any time if my statement is found to be incorrect even after my graduation, the university has the right to withdraw/cancel my M.Phil. degree.

Name of student: Saneed Khaliq

Date: ___________________________

THESIS COMPLETION CERTIFICATE

Student's Name: Dr. Saneed Khaliq Registration No. 66219

Program of Study: M.Phil. (Anatomy)

Thesis Title: Evaluation of proximal femur geometry on plain radiographs among different ethnic groups

It is to certify that the above student's thesis has been completed to my satisfaction and to my belief. Its standard is appropriate for submission and evaluation. I have also conducted plagiarism test of this thesis using HEC prescribed software and found similarity index at _______% that is within the permissible limit set by the HEC for the M.Phil. degree thesis. I have also found the thesis in a format recognized by the BU for the M.Phil. thesis.

Principal Supervisor's Seal &Signature: ___________________________

Date: _______________________ Name: Prof. Dr. Aisha Qamar

THESIS COMPLETION CERTIFICATE

Student's Name: Dr. Saneed Khaliq Registration No. 66219

Program of Study: M.Phil. (Anatomy)

Thesis Title: Evaluation of proximal femur geometry on plain radiographs among different ethnic groups

It is to certify that the above student's thesis has been completed to my satisfaction and to my belief. Its standard is appropriate for submission and evaluation. I have also conducted plagiarism test of this thesis using HEC prescribed software and found similarity index at _______% that is within the permissible limit set by the HEC for the M.Phil. degree thesis. I have also found the thesis in a format recognized by the BU for the M.Phil. thesis.

Co-Supervisor's Seal &Signature: ____________________

Date: 1st July, 2021 **Name:** Surg. Cdr. Dr. Muhammad Usman Khan

PLAGIARISM UNDERTAKING

I, solemnly declare that research work presented in the thesis titled **"Evaluation of proximal femur geometry on plain radiographs among different ethnic groups"** is solely my research work with no significant contribution from any other person. Small contribution/ help wherever taken has been duly acknowledged and that complete thesis has been written by me.

I understand the zero-tolerance policy of the HEC and Bahria University towards plagiarism. Therefore, I as an Author of the above titled thesis declare that no portion of my thesis has been plagiarized and any material used as reference is properly referred/ cited.

I undertake that if I am found guilty of any formal plagiarism in the above titled thesis even after award of MPhil degree, the university reserves the right to withdraw/ revoke my MPhil degree and that HEC and the University has the right to publish my name on the HEC / University website on which names of students are placed who submitted plagiarized thesis.

Student / Author's Sign: _______________

Name of the Student: Dr. Saneed Khaliq

DEDICATION

To my Supervisor Prof. Dr Aisha Qamar

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1.	FHD	Femoral head diameter
2.	FND	Femoral neck diameter
3.	FNL	Femoral neck length
4.	IL	Intertrochanteric length
5.	MO	Medial offset
6.	VO	Vertical offset
7.	FVO	Femoral vertical offset
8.	FAL	Femoral axis length
9.	HAL	Hip axis length
10.	NSA	Neck shaft angle
11.	FNSA	Femoral neck shaft angle
12.	CT	Computerized tomography
13.	MRI	Magnetic resonance imaging
14.	KUB	Kidney ureter bladder
15.	BMI	Body mass index
16.	AP	Anteroposterior
17.	PA	posteroanterior

ABSTRACT

Studies on human proximal femur have been done in different areas of the globe. Variations are found due to different levels of activity, race, genetics, clothing, lifestyle and occupation. Accurate description of femoral morphometry is of great interest for biomedical engineers and orthopedic surgeons, but data from different populations is lacking. Such important data happens to be relevant for surgical issues such as for planning surgery and intervention, correction of neck shaft angle, insertion of surgical screws after a fracture and most importantly for prosthesis and implant design. Adequately shaped implants are critical for fixation of femur after fracture or total hip arthroplasty to reduce implant related complications such as change in leg length, dislocation from improper positioning of implants, implant loosening and dislocation fractures. Significant differences have been noted among African Americans, Caucasians, Chinese and other Asian populations. Femoral head diameter (FHD), femoral neck diameter (FND), femoral neck length (FNL), intertrochanteric length (IL), medial offset (MO), femoral vertical offset (FVO), femoral axis length (FAL), hip axis length (HAL) and neck shaft angle (NSA) are morphological parameters of human proximal femur, taken for diagnosis and surgical intervention. Objective of this study were to compare the differences in proximal femur geometry of right and left femur. To compare the differences in proximal femur geometry among male and female. To compare differences among different ethnic groups and to study associations of proximal femur geometry with BMI, lifestyle factors and comorbidities. The study was conducted in PNS Shifa hospital Karachi from September 2020 to March 2021 after Ethical approval from Bahria University Medical and Dental College. After an informed consent, anteroposterior radiographs of both hips of 75 adults aged 20-70 years were included in the study. This study was designed to compare differences of proximal femur parameters between male and female gender, right and left, different age groups and most importantly between 5 ethnic groups of Pakistan and to note any variations. Statistically significant results were observed between gender in all parameters of proximal femur. The mean values of HD in males was 52.95±2.58mm and females was 45.96±3.08mm. mean value for FND in male was 38.03±3.63mm and in female was 31.99±2.65mm and this was statistically significant (p-value = 0.000). FNL in male was 53.10±7.96mm and in female was 45.82±6.41mm. The obtained mean value of femoral intertrochanteric length in male was 68.93±5.29mm. The mean value in females was 68.93±5.29mm. Mean of the values of femoral medial offset in males was 39.67±7.98mm. The mean value in females was 34.53±6.94mm. In males the mean femoral vertical offset value was 61.82±8.39mm and in female the mean value was 49.02±8.18mm. The following means were observed for male and female FNAL was 108.78±7.16mm for male and 94.47±7.04mm for female. The mean hip axis length (HAL) in males was found to be 126.46±8.19mm and in females it was observed to be 106.21±9.28mm. The mean value of NSA of male was 132.23±5.544º and female was 132.085±6.597º. there was insignificant decrease in NSA between male and female. Significant ethnic differences and a decrease of NSA in age group is observed. It can be concluded that understanding and knowledge of proximal femoral morphometry including variations and correlations among them is vital for an orthopedic surgeon before undertaking any surgical procedure or selection of a proper implant for the patient. Knowing morphological parameters of a population is necessary for designing appropriate medical devices and prosthesis that fit accurately to that population and minimize complications such as implant loosening and implant related fractures.

KEYWORDS: Proximal femur, Orthopedic implants, Ethnic groups, Plain radiographs

CHAPTER 1

INTRODUCTION

The femur or the thigh bone is the longest, strongest and heaviest bone of the human body. Proximally the bone has pyramid shaped neck which at apex attaches with the spherical head and at the base with the cylindrical shaft. There is presence of two bony protrusions, at the proximal end, the greater trochanter, which is the lateral most palpable projection and the lesser trochanter on the posteromedial side of femur providing attachment to the important muscles of the hip and knee (Amy Chang, Breeland, & Hubbard, 2020). The morphological and geometrical aspect of femur and the relation between the parameters such as head, neck, neck shaft angle, trochanters has been a subject of study and discussion in field of orthopedic dating back to the 19^{th} century (Toogood, Skalak, & Cooperman, 2008).

Proximal femur is an area susceptible to a number of childhood and adult disorders, many of which can be linked to differences in shape. The treatment that can benefit them, emerges from a detailed understanding of this region. Proximal femur contains the head of femur, the neck and the area 5 cm distal to lesser trochanter. An inclination angle of 125º - 135º is seen between the head, neck and shaft of femur. In addition, there is an inversion angle of 15º between femoral head condyles and femoral neck. The articular portion of femur with acetabulum is about two-third of sphere, functioning to provide dynamic support to weight of the body and helps in transmission of load from axial skeleton to the lower limbs for mobility (Ramage & Varacallo, 2021), (A. Chang, Breeland, & Hubbard, 2021). Femoral head of a normal hip coincides exactly with the center of acetabulum. The fovea or the capitis femoris is located at the top of the femoral head medially, providing an area for the attachment of the ligamentum teres. The greater trochanter is present at the junction of femoral neck and body of femur providing an area for attachment of the abductor muscles. It is present at the same level as femoral head center, while the lesser trochanter is positioned below the femoral neck along the inner back surface of the body of femur, providing attachment to the iliopsoas muscle (Eyüboğlu et al., 2020).

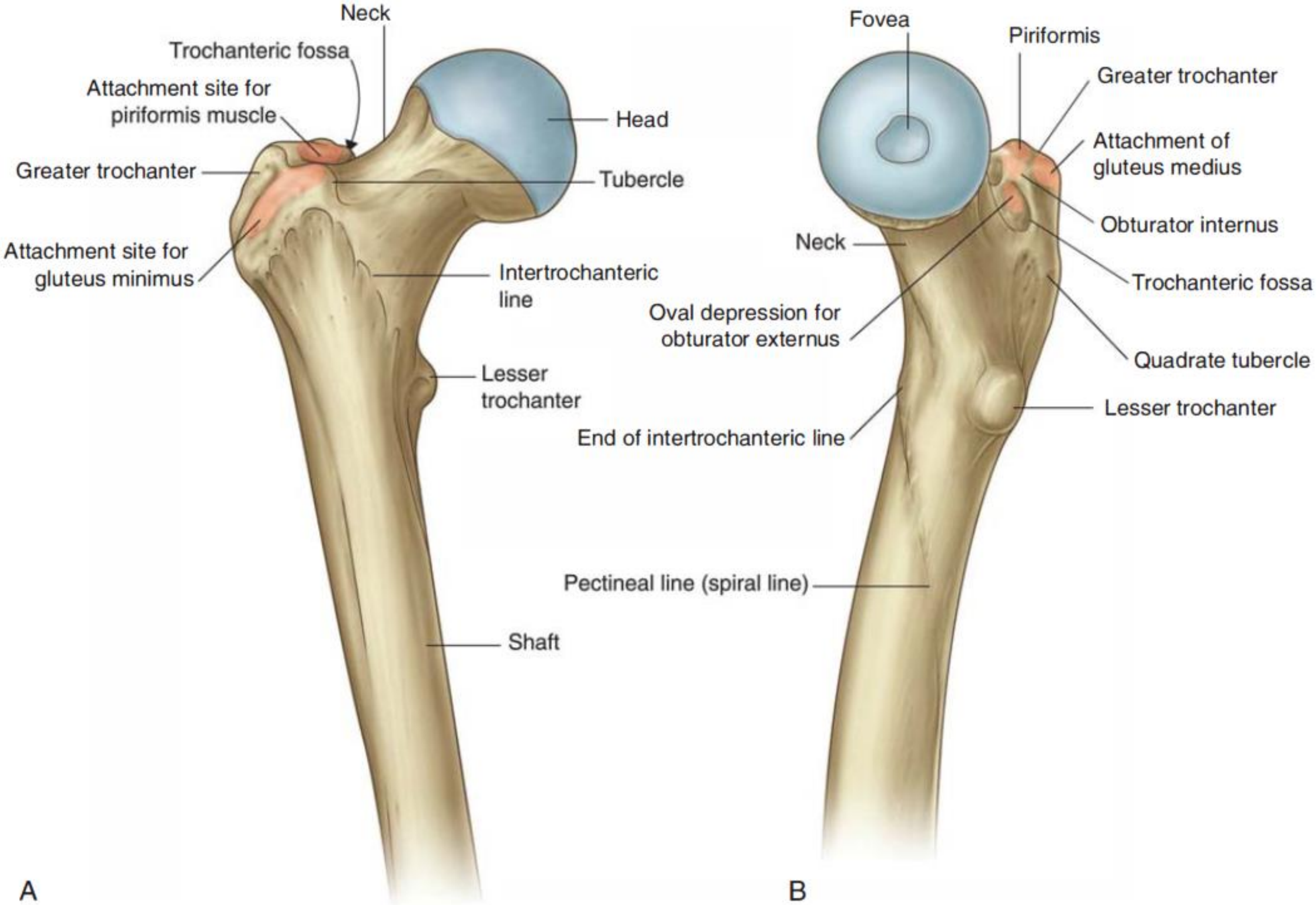


Figure-1. Proximal end of femur (right) anterior view (B) Proximal femur posterior view (Drake, Vogl, & Mitchell, 2009)

1.1 Proximal femur development

The development of the proximal femur begins at 4th week of intrauterine life and develops postnatally through puberty. Different and complex signaling pathways contribute to the growth differentiation and maturation of structure such as bone, muscle, tendons, cartilages and joints resulting in complex structure that is responsible for support and stabilizing the body weight and helps in mobility. Understanding the geometry of proximal femur and anatomical structures provides a guide for approach and treatment of the fractures of this region (Konda, 2018). A series of complex physiological and biomechanical factors lead to development of intrauterine proximal femur.

The limb formation starts by the end of 4th week of intrauterine life, with activation of collection of mesenchymal cells in somatic lateral mesoderm (Moore, Persaud, & Torchia, 2015). During the 6th week of embryonic life, within the embryo an area condenses to shape the ilium, ischium, pubis and the femoral shaft followed by rapid differentiation while the head of femur appears during the 7th week. Three separate layers form the perichondrium of the acetabulum and the head of femur together with the synovial membrane (Amy Chang, Breeland, & Hubbard, 2018). During the 8th week of embryonic life, blood vessels are grown into ligamentum teres. Angle formation of the neck and shaft occurs, true joint cavity begins to form by apoptosis. Acetabular labrum becomes identifiable at 11th week. The femoral head starts becoming spherical in shape and is now 2mm in diameter which is separate from acetabulum. During this stage, hip can be dislocated experimentally. Neck shaft angle at this stage of life is about 140º - 150º and femoral anteversion is between 5º - 10º, vascular supply is established now (Amy Chang et al., 2018).

During 16th week the hip muscles are developed enough that the fetus can kick and move. The femoral shaft starts ossification but the head of the femur and trochanters remain cartilaginous at this stage until the birth (Amy Chang et al., 2018). At birth the diaphysis of the bone is ossified but epiphysis, the two ends are still cartilaginous. Their ossification soon occurs with ossification center in the epiphysis (Sadler, 2018).

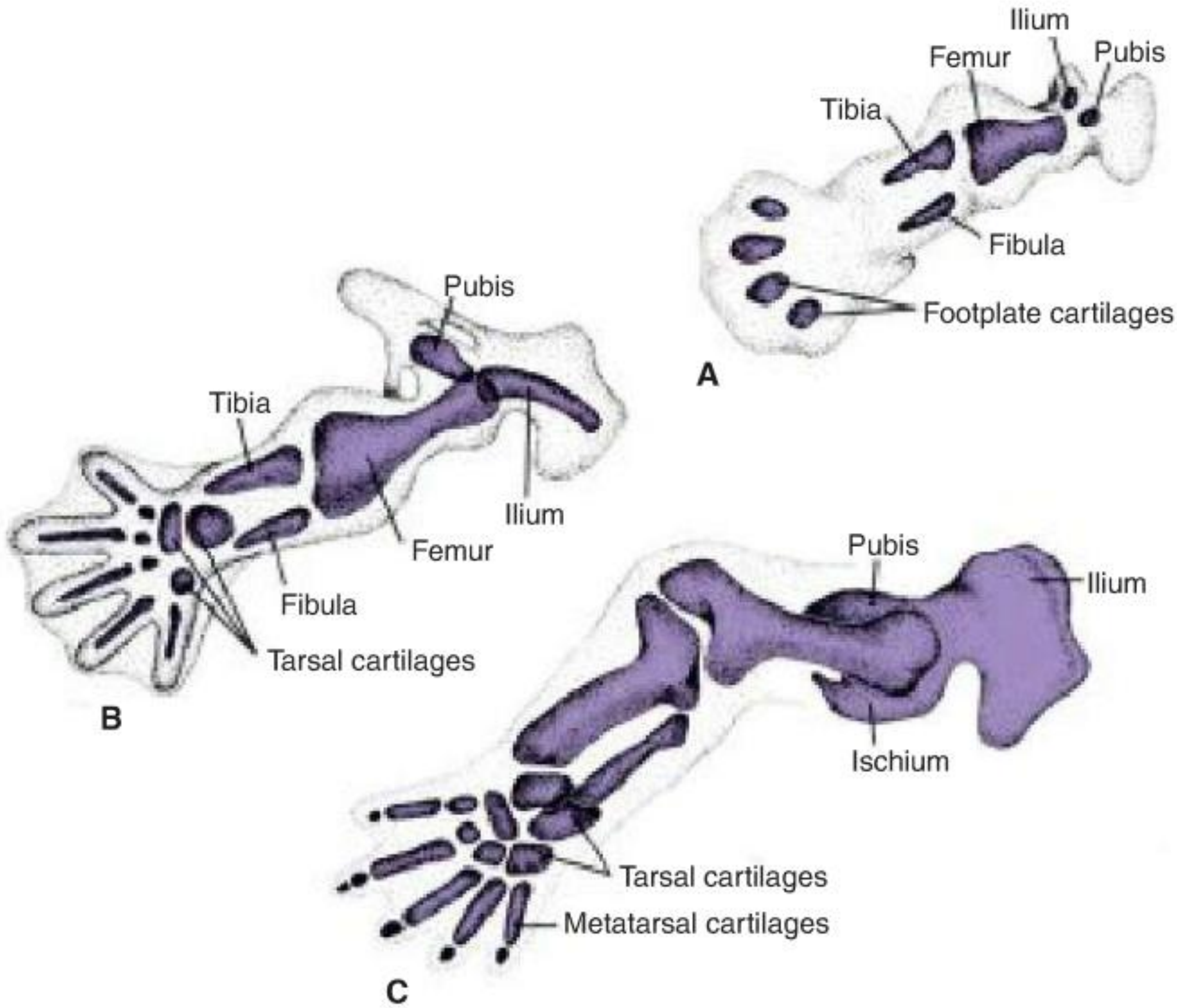


Figure-2. Six weeks embryo (A) showing model of first hyaline cartilage in lower extremity (B) model of cartilage by the end of sixth week (C) Model of cartilage at the beginning of eighth week.

1.2 Proximal femur geometry

A continuous relationship exists between the head, neck, greater trochanter and shaft of femur in grown adults. The relationships are vital to define because normal relationships should be established in course of operative treatment of proximal femur fractures. The normal tip of trochanter and femoral head center line in an axis of 90º±5º (Egol & Leucht, 2017) and axis of neck with an upper limit to be 140º and lower limit 114º (Fischer et al., 2020).

1.3 Bony architecture of proximal femur

Several studies have been done for defining bony architecture of the proximal femur. Two bony trabecular columns, a vertical and a horizontal column are present in the proximal femur with its base in the lower neck of femur and ascends to the head of femur (Figure-3). It conveys compression force. The horizontal column has its base in the proximal shaft and extends horizontally to the femoral head. It carries tension force of femur (Hammer, 2019). Secondary trabeculae are formed according to mechanical load and unloading of bone, in case of increased load the bone remodel's itself and becomes stronger. Studies of modern human show trabecular bone variations due to different levels of activity and mobility (Doershuk et al., 2019), (Chirchir, Ruff, Junno, & Potts, 2017), (Ryan & Shaw, 2015).

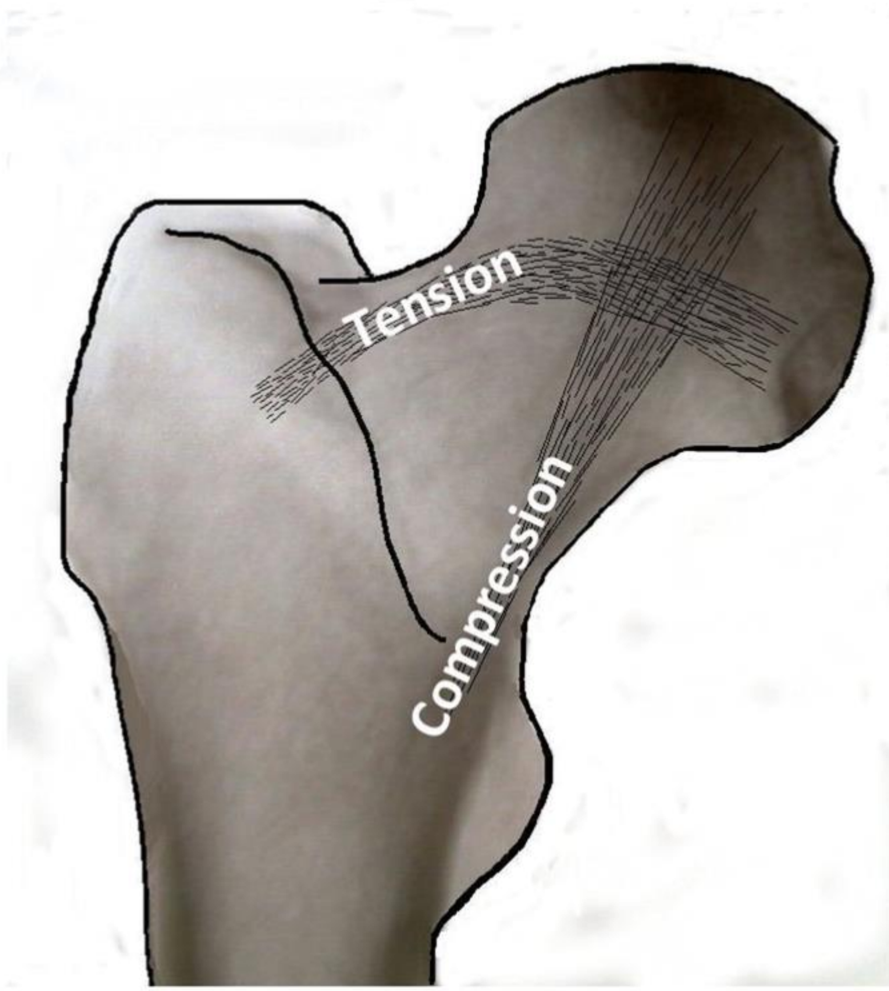


Figure-3. Schematic diagram showing configuration of vertical column and horizontal column within femoral neck (Hammer, 2015).

.

1.4 Relationship of Hip Joint with proximal femur

The hip joint or the acetabulofemoral joint is a ball and socket joint which articulates the head of the femur to the acetabulum of the pelvis. The femoral head is almost spherical in shape, and the joint is congruous only in the weight bearing area. The head is the upper most structure which projects from the medial side and faces upward, forward and medially. It articulates with the acetabular cavity of pelvis to form the hip joint. (Figure-4) The head of femur attaches to the acetabulum by ligamentum teres which is present inferior and posterior to the center of the head of femur. The joint provides support to the weight of the upper body and trunk and allows force transmission to the lower portion of the body from the axial skeleton and allows the joint for different movements. Movement in three axes is allowed by the hip joint that are perpendicular to each other (Ramage & Varacallo, 2021). The central, axis is at the femoral head. Flexion and extension are possible in transverse axis. The internal and external rotation is possible in longitudinal axis. The sagittal axis allows adduction and abduction. In addition to different movements, the joint also helps in weight bearing. Hip stability is maintained by several factors like depth and shape of acetabulum which surrounds the whole head of femur. The acetabular fibro cartilage collar provides load transmission, maintenance of negative pressure and regulation of synovial fluid hydrodynamics (Ramage & Varacallo, 2021),(C. Chang, Jeno, & Varacallo, 2021).

The femoral neck connects the head of the femur to the shaft and provides stability during the movement. The angle formed between the obliquely oriented femoral neck with the vertical shaft is called the neck shaft angle which is about 120 to 145 degrees with an average of 135 degrees. It enables the lower limb to move clear of the pelvis (Prasad, Shivashankarappa, Pavan, Shruthi, & Saheb, 2017)

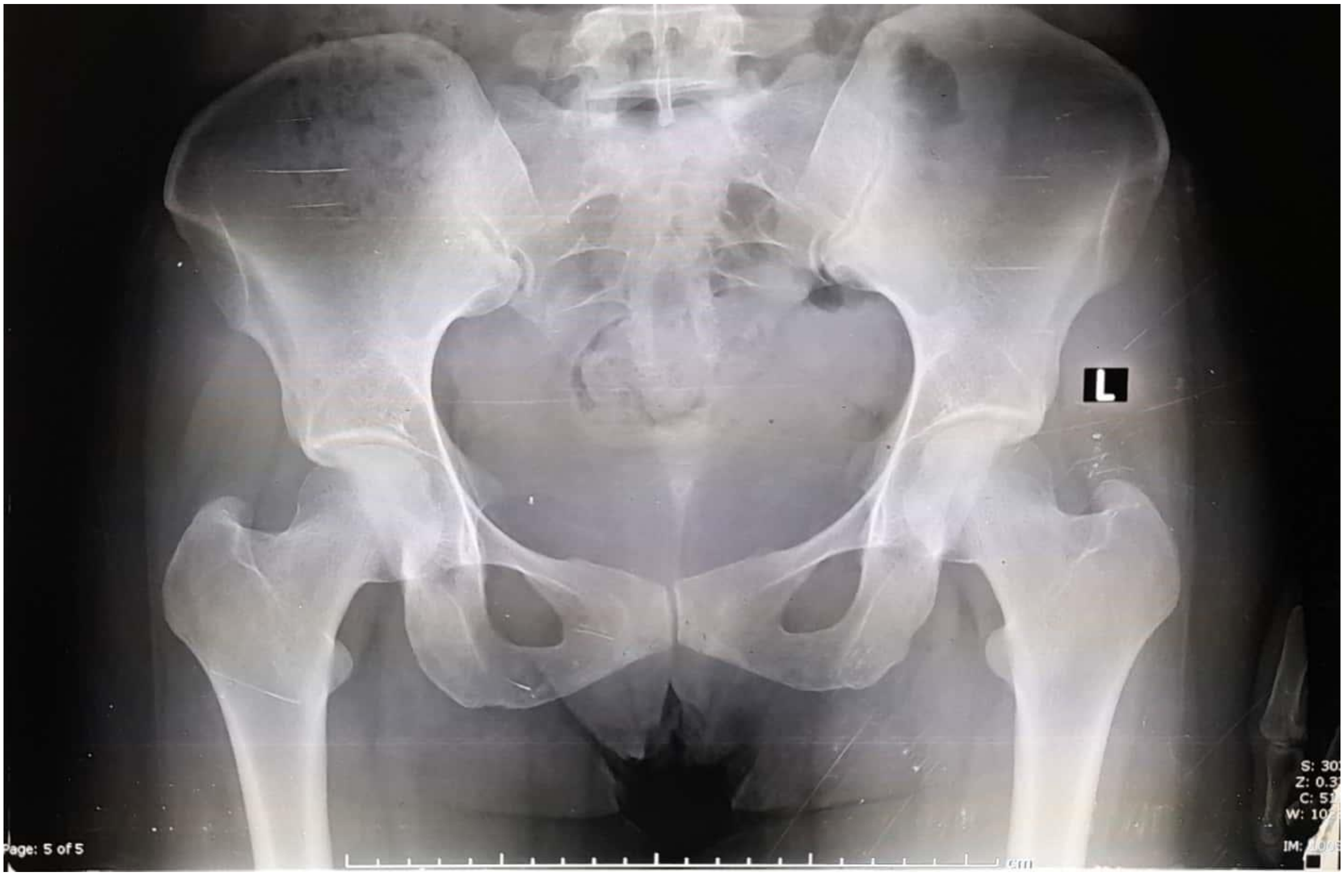


Figure-4. Standard anteroposterior (AP) hip radiograph

1.5 Femoral neck shaft angle and its variations

The angle is variable in different populations of the world; variations are related to genetics, environment, climate adaptation, agriculture, urban adaptation, nutritional status, sedentary lifestyle, clothing, gender, age and geography. There are no age-related differences in adults, but possibly a slight lateral difference that could be due to right leg dominance. Median Neck shaft angle, is more in warmer areas, especially in the Pacific region which is about 130°, whereas lesser values are seen to be associated with a stockier body build and are found in regions where populations were adopted to cold conditions such as in Europe which is about 126° and the Americas with 125°. There is a moderate trend towards increasing Neck Shaft Angle with the economic transitions from forager to urban and agricultural way of life and, from a mobile to a desk bound life style (Gilligan, Chandraphak, & Mahakkanukrauh, 2013).

1.6 Fractures of Proximal Femur

Hip bone fractures have a great burden on the patient as regards in morbidity, mortality and medical costs and are one of the major problems in the elderly population due to the shape of the proximal femur. A bone when subjected to stress is fractured if the force applied is greater than the strength. Geometric arrangement, material of bone and the strength of force contribute to the type of fracture. The risk of fracture can be predicted by some elements such as bone mineral density, intensity and the direction of the fall, body mass index, femoral shape and life style factors. Elderly population residing in nursing homes have a higher risk of hip fractures which is 5 to 6% and incidence of fall is 1.5 falls per person annually and 20% of these fall lead to hip fracture. Elderly women and post-menopausal women are at a higher risk of hip fractures due to the large reductions in bone mineral density that occur in the first few years after the menopause. The prevalence is about 14% in postmenopausal women and is 6% in elderly men population. This incidence increases with the advancement of age. Postmenopausal women who have suffered an earlier fracture of another bone have an increased risk of hip fracture later in life (Lauritzen, 1996). About 620,000 cases of hip fracture are reported annually in the European Union and 42,10,000 in the Unites States. Its effects the quality of life of the patient; a large number of patients are unable to return back to their previous life and need a longer period for recovery and support (De Bustamante et al., 2018).

1.6.1 Fractures of femoral neck

Fractures of femoral neck is a major cause of morbidity and disability in older population. Low energy fall leads to major old age proximal femur fractures, requiring urgent operative treatment and hospitalization. Surgical procedures include internal fixation, closed reduction, and hemi and total hip replacement. Surgical decision taking depends on patient’s condition, pattern of fracture and experience of the surgeon. (Ju, Rajaee, Mirocha, Lin, & Moon, 2017)

The optimal neck fracture treatment is a point of debate. Fractures which are not displaced need a closed reduction and percutaneous pinning while studies show that displaced fractures of femoral neck have a higher success rate if total or hemiarthroplasty is done. Recent guidelines from American academy of orthopedic surgeons highly suggest total hip replacement or hemiarthroplasty for femoral neck fracture which is displaced (Ju, Rajaee, Mirocha, Lin, & Moon, 2017).

Proximal femoral fractures especially fractures of neck are uncommon in children, comprising of less than 1% of childhood fractures. Cause is due to the high energy trauma from an accident or fall from a height. Pathological fractures due to low energy trauma and stress fracture are also present but are very rare. Despite being uncommon, major long-term complications can result due to tenuous blood loss and anatomical differences in children (Palocaren, 2018).

1.7 Race and Ethnic variations of proximal femur

Studies of proximal femur show variations in different population around the globe. Data of hip fracture of United States African American, Asian and Hispanic population are considerably less than white men. Areal bone mineral density is an essential fracture risk factor among males. Studies show that femoral neck and total hip bone mineral density are greater in African American than white population of same age groups, while hip bone mineral density measurements appear to be lesser or similar in Asian and Hispanic men compared with whites of same age groups. The presence of differences in proximal femur between different populations suggest that there are periosteal and endosteal modeling and remodeling and modification with aging (Marshall et al., 2008).

Osteoporosis related bone changes are also seen in human proximal femur. Morphological analysis of the bone biopsies showed changes due to alteration in bone properties. Structural analysis via high resolution computed tomography showed a significant rise of anisotropy of tissue mineral density in osteoporotic patients while other parameters of humeral head were statistically non-significant. Osteoporosis patients due to decreased trabecular connectivity show a lesser mechanical to compression load strength. Hydroxyapatite crystallite size is increased in osteoporosis patients leading to reduced compressive loads. Thus, it can be concluded that osteoporosis affects bone mineral density which leads to morphological and mechanical alteration of bone features (Molino et al., 2019).

1.8 Anatomy of Proximal Femur

1.8.1 Shape

Anatomy of proximal femur plays a vital role for understanding various pathological entities and their processes. Studies show that femoral neck shaft angle under 129º is at a higher risk of developing idiopathic femoral head osteonecrosis. Studies correlate this parameter with anteversion and retroversion of femoral neck in its physiopathology. Anatomy and anatomical variations are essential for better understanding of human hip biomechanics, analysis of diagnostic imaging and choice of treatment. A comparison of measurements between normal and pathologic conditions is of utmost importance. Geometry of proximal femur plays a vital role in this regard due to occurrence of different hip pathologies in children and adults too. Accurate reconstruction of parameters of hip is of great importance for a successful total hip replacement. Inaccurate restoration of parameters after surgical intervention such as in total hip arthroplasty may lead to gait disorders, instability of prosthesis and weakness in muscle strength and function, affecting the quality of life and negatively related to survival of implant. Moreover, studies show impairment of recent cementless stem designs for restoration of accurate anatomy of hip particularly femoral offset leads mismatch of 30%.

1.8.2 Angles

Angles of femur include femoral neck shaft angle (FNSA) and torsion angle. FNSA also known as centrum collo-diaphyseal angle is a vital measurement present between the longitudinal axis of femoral neck and femoral shaft (Figure-5). It is also a great indicator of different pathologies of proximal femur and outcome therapy in corrective osteotomy. (Srisaarn et al., 2019)

1.8.3 Torsion angle

One of the important parameters in the femur is femoral neck torsion angle. (Figure-6). It is of utmost importance in deciding screw space configuration in cases of neck fracture. Studies suggest that screws placed within 3 mm of neck of femur have the highest ratio of union after fracture (Zhu, Shi, Xu, & Yuan, 2019). Femoral torsion is recognized to be an essential factor in assessment of young patient with groin pain and reduce and limit the range of motion. For correction of abnormal femoral torsion derotational osteotomies are done but can be complex and challenging. (Buly, Sosa, Poultsides, Caldwell, & Rozbruch, 2018). Measurement of torsion angle are also important for patients undergoing for joint preserving surgery. Various techniques are introduced for torsion angle. Abnormalities of femoral torsion is associated with pain of the hip and is categorized to increased and decreased torsion. Causes of increased torsion include tripping, in-toe gait and pain and instability in patellofemoral joint. Even though most abnormalities of torsion are developmental but some of them can be acquired and cause changes in the gait and can cause lower limb symptoms. Association of increased femoral torsion is seen with lower external femoral rotation and increased hip internal rotation. Similarly, association between lower torsion angle and higher external femoral rotation is seen and lower internal hip rotation (Hatem et al., 2021).

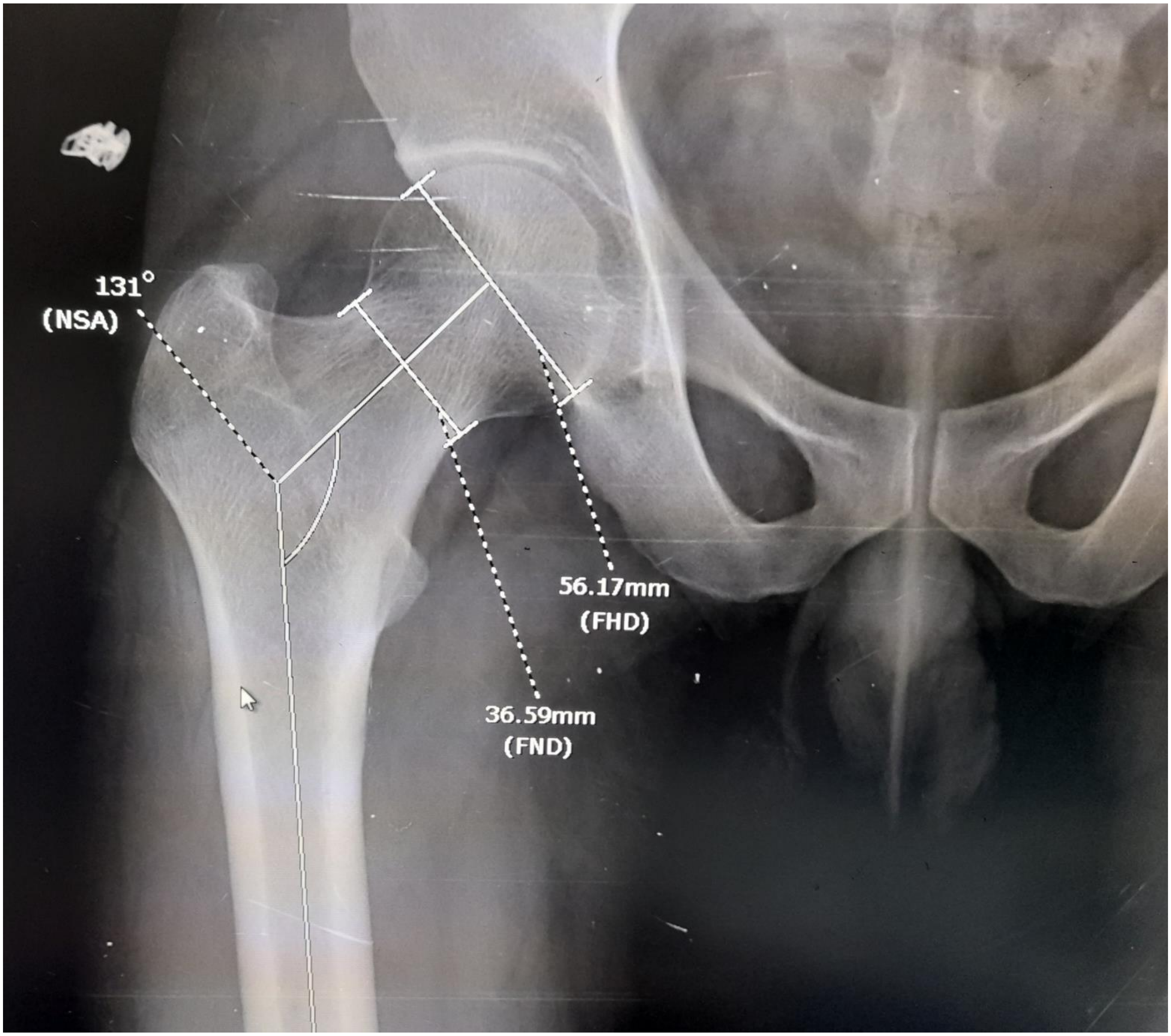


Figure-5. X-ray Hip AP view: Neck shaft angle (NSA) is angle formed by line drawn from femoral shaft axis and line drawn along femoral neck axis passing through center of femoral head. Femoral neck diameter (FND), measured by taking distance in sagittal plane from the middle of neck. Femoral head diameter (FHD), a line drawn perpendicular from center of femoral head.

1.8.4 Anteversion

Anteversion of femur is the angle between the long axis of femoral neck and coronal axis of condyles of femur with knee and ankle (Figure-6). The normal values range from 10°-15°. If the angle of femoral anteversion is too small there is impingement of joint anteriorly and internal rotation is decreased (Hu, Zhan, & Cai, 2021)

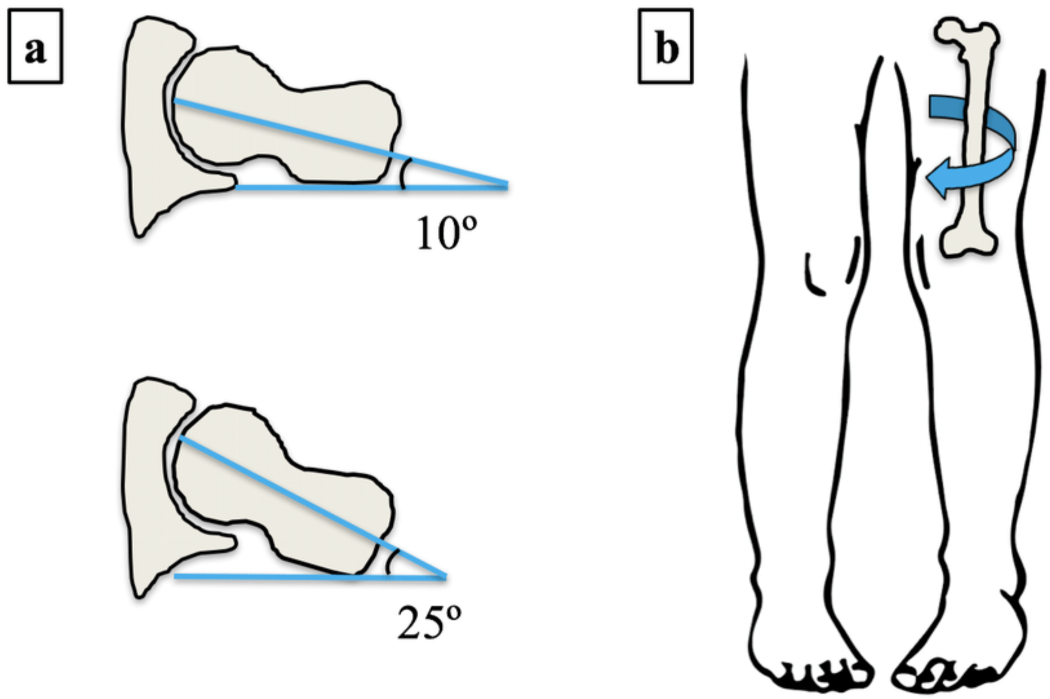


Figure-6. Effect of Femoral anteversion on the lower limb. (a) image showing a normal anteversion of 10°, the image below shows an excessive anteversion of 25° (b) Image showing femoral anteversion and an increase in internal rotation of hip (Goyal, Moulton, & Dewald, 2019).

1.9 Muscle attachments of proximal femur

Muscles arising from the hip and attaching to the proximal femur have an important role in movement and activity (figure-7). These muscles are responsible for stability of gait. Muscles originating from the pelvis and inserting on the anterior and posterior surfaces of the femur help the hip joint with flexion and extension. Muscles of the proximal femur have a deforming force in case of a fracture. These muscles impart a change in normal position across the fracture. The head and neck of femur usually remain in position. Hip abductors present at greater trochanter are responsible for its abduction while short external rotators and piriformis externally rotates the greater trochanter. Iliopsoas tendon present at lesser trochanter tends to adduct and flex the bone. Hamstring and adductors at femoral shaft move the bone to a medial and posterior direction. Gluteus maximus rotates the femur externally and extends it. Muscles such as hamstring and quadriceps apply forces which reduce the axial length of femur (Mokawem, Bobak, & Aderinto, 2012)

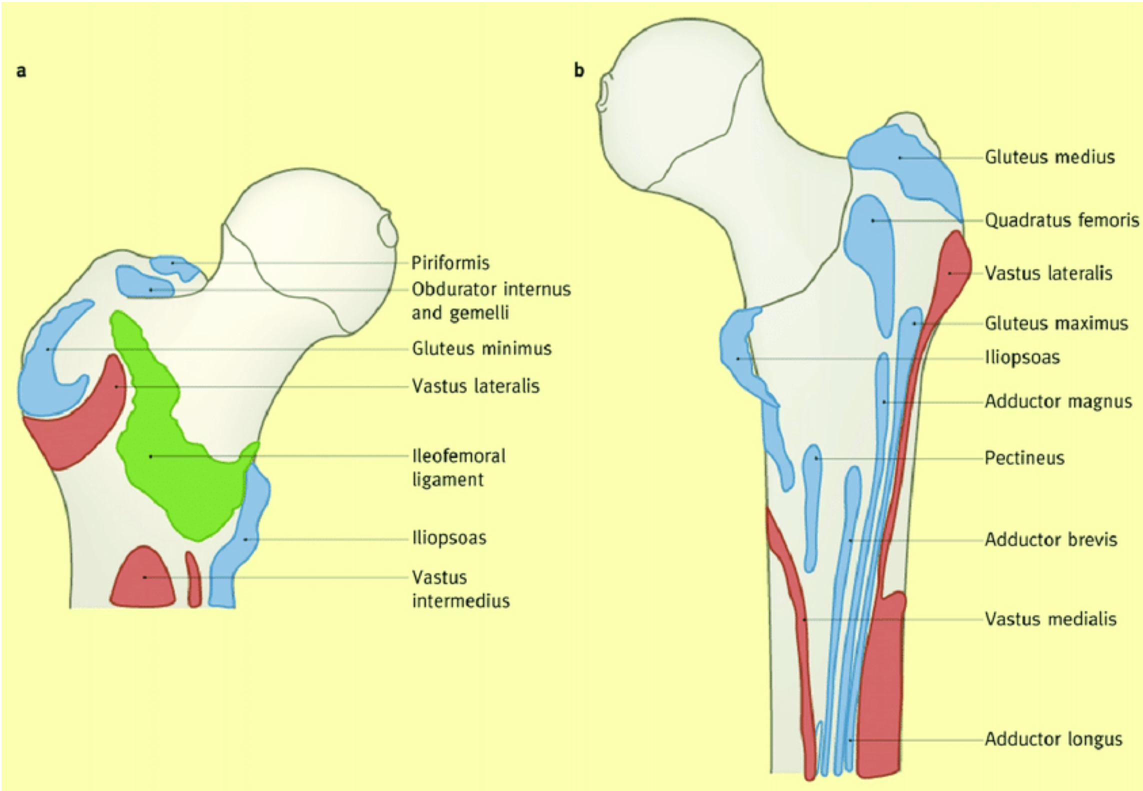


Figure-7. (a) Muscle attachments of proximal femur (anterior view). (b) Muscle attachments of proximal femur (posterior view) (Mokawem et al., 2012).

1.10 Vascular Supply of proximal femur

The vascular supply of proximal femur is necessary for finding possible risk of avascular necrosis of the femoral head after a fracture. Medial femoral circumflex artery and inferior gluteal arteries are the main arteries that supply the head and the neck of femur. Medial femoral circumflex artery originates as a posteromedial branch from the deep femoral artery, which itself is a branch of femoral artery (Figure-8). Branches of Medial femoral circumflex artery run medially and posteriorly between pectineus and iliopsoas muscles of the thigh. It is the chief artery of the femoral head and neck. Current research shows inferior gluteal artery as the dominant artery that provides sufficient blood supply to the femoral head. Medial circumflex artery anastomosis with the distal deep branch of the inferior gluteal artery and enters the posteroinferior hip capsule. Minor contribution to vascular supply is also supplied by the lateral circumflex artery, superior gluteal artery, acetabular branch of superior gluteal artery and obturator artery (Lu & Uppal, 2019). Femoral head fractures are rare and almost always occur by dislocation of the head due to fall, accidents and sports injures present with localized hip pain and patient is unable to bear weight. This type of injury leads to disruption of the blood supply to the femoral head and avascular necrosis (Lo, Talkad, & Sharma, 2020).

1.11 Femoral Head diameter

The head is the most proximal part of the femur that articulates with the pelvic acetabulum and forms the hip joint. Head is held in position by the neck. It is smooth, nearly spherical in shape and covered by articular cartilage with a medial depression called the fovea capitis, a site for the attachment of the ligamentum teres. The head has a significance clinically due to the avascular necrosis by the dislocation and fractures. The head of femur is removed in total hip arthroplasty. Due to smooth and sphere shape, the head of femur act as a ball in the socket and allows a wide range of movements. The head is accommodated by the lunate surface of the acetabulum. Bone curvature is formed by Wolff's law that provides support to the axial body weight (Lo et al., 2020). Measurement of femoral head is of utmost importance for a surgeon while performing a surgical procedure such as total and hemiarthroplasty.

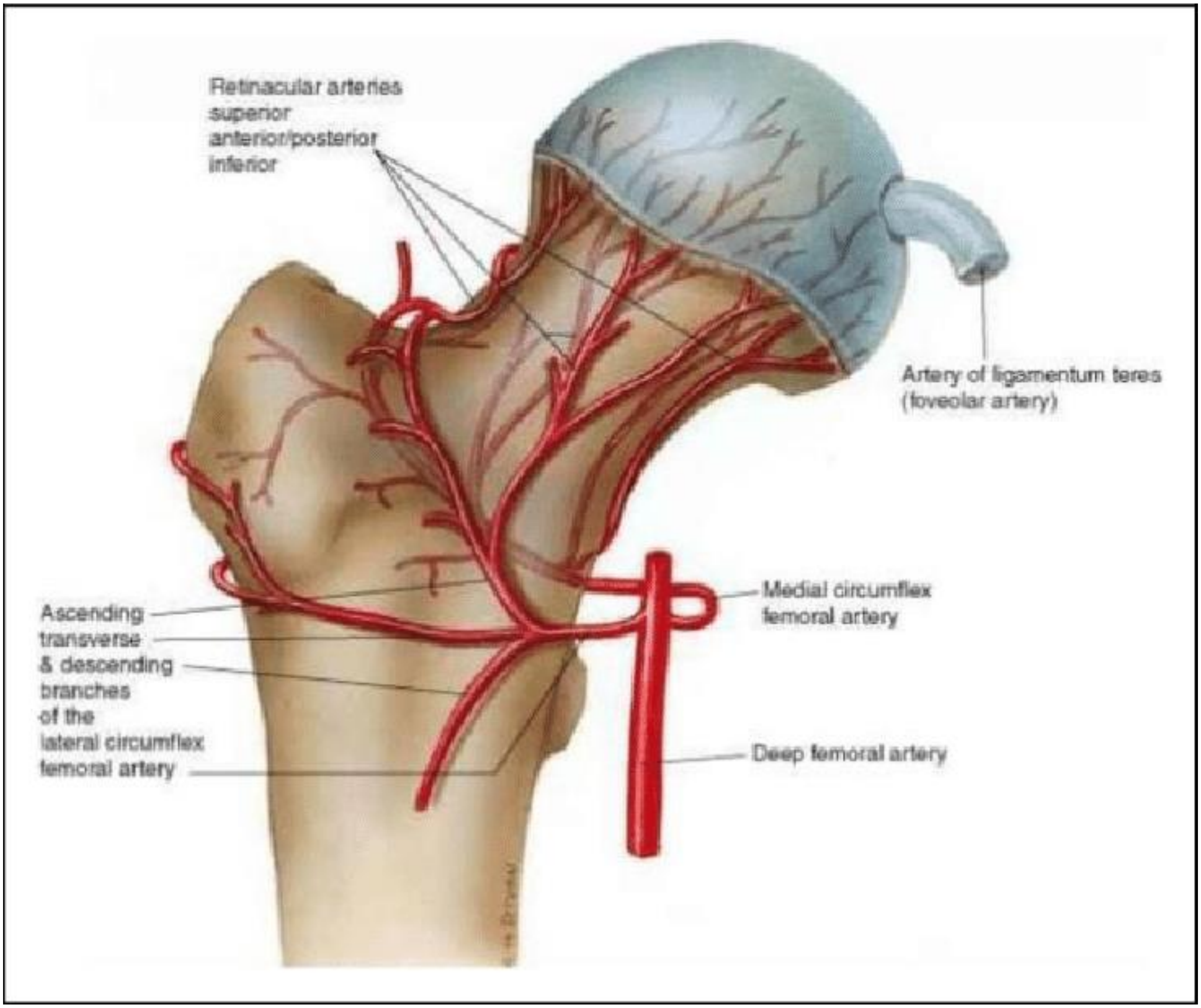


Figure-8. Image showing deep femoral artery and medial circumflex artery and its branches supplying the femoral head and neck (Lu & Uppal, 2019).

Postoperative complications after total hip arthroplasty are reduced by increasing the size of femoral head implant. This method reduces the dislocation of head by greater jumping distance and a higher range of motion is allowed. Use of large diameter heads have lower chances of dislocation but can lead to further complications such as pseudo tumors (Zijlstra, De Hartog, Van Steenbergen, Scheurs, & Nelissen, 2017).

1.12 Femoral neck diameter

Femoral neck connects the spherical head with the cylindrical shaft and is about 5cm in length. Neck is measured by taking distance in sagittal plane from the middle of neck. Fractures of neck are less common in young adults as compared with elderly population. Despite the advancements in surgical approach and management, still complications such as nonunion and avascular necrosis remains high. A better understanding of the femoral neck anatomy and its relation to the femoral neck fractures can lessen the complications and can lead to higher successful outcomes. The connection and junctional location of neck with head and shaft makes it more prone to fractures. The vascular supply of the head runs along the neck; dislocation of head and compromising the vasculature from above makes the surgery more challenging for the surgeon. Timely diagnosis and surgery can prevent complications of joint.

Hip fractures in young adults are due to high energy trauma such as automobile accidents while fractures in elder population are from low energy fall. Hip fractures are more common in females comprising of 70% of all hip fractures, and even more numerous in white females. Approximately 1.6 million fractures of hip are reported annually (Hayat & Varacallo, 2020).

1.13 Fractures of neck

Fractures of femoral neck are classified by Garden and Pauwel, which are widely used and have classification according to severity and subcapital fractures.

1.13.1 Garden Classification:

Garden Types I: Nondisplaced and incomplete fracture

Garden Type II: Nondisplaced and complete

Garden Type III: Partially displaced and complete

Garden Type IV: Fully displaced and complete fracture

For further simplicity it sometimes can be classified as nondisplaced and displaced fractures (Kazley, Banerjee, Abousayed, & Rosenbaum, 2018).

1.13.2 Pauwels Classification:

Types I: fracture having an obliquity less than 30º in which the compressive forces are dominant

Type II: 30º to 50º due to higher angle the shearing force occurs and negatively effects fracture healing

Type III: Greater than 50º. The shearing forces are high and can lead to displacement and effects bone healing negatively

Pauwels classification is a biomechanical classification using the inclination angle between fracture line of distal fragment relative to the horizontal. This was introduced in 1935 in a German journal, which showed that a higher angle and higher horizontal fracture has greater instability (Shen, Wang, Chen, Rui, & Zhao, 2016).

1.14 Femoral neck length

Femoral neck length can be defined as the measurement from the axis of femoral shaft to the center of femoral head in a central axis along the neck.

Difference in incidence of hip fracture is seen in different ethnic groups. Studies suggest that femoral neck length has a contribution in these fractures. A higher incidence is seen in Europeans and least in Mexican-Americans and Asians. Along with the femoral neck length, dietary habits, lifestyle factors, bone density, height and built also contribute in these types of fractures.

Femoral neck length measurement plays a key role in internal fixation after a femoral neck fracture. Sliding hip screws and canulated screws are two widely accepted treatment options in a nondisplaced fracture of neck. Post-operative complications such as femoral neck shortening has been seen in 31-66% of cases, leading to gait disturbances and poorquality life. To overcome these complications non-sliding, length stable prostheses are used (Chiang, Wang, Fu, Hung, & Yang, 2019).

1.15 Hip Axis Length

A significant risk factor of proximal femur is identified to be the hip axis length. A study in elderly women showed positive correlation between the hip axis length and hip fracture risk, independent of bone mineral density, height and age. Principles of biomechanics may be applicable to this that greater the length, the less force is needed to break or bend. Another clarification can be that in individuals whose hip axis is greater, have a more protruded greater trochanter which is more likely to be impacted in case of a fall. Various other studies have also found influence of proximal femur geometry on hip fracture risk. Several studies conclude that hip axis length could contribute to hip fracture risk as seen in studies on Mexican-Americans, African-Americans women, Japanese and other Asian population as compared with European population. A study on Siri Lankan women also showed association of long hip axis length with fracture (Arachchi, Pinto, & Technology, 2020), (Chin, Evans, Cornish, Cundy, & Reid, 1997).

1.16 Femoral axis length

Femoral axis length is defined as a linear distance from the greater trochanter base to the femoral head apex. Recent studies in forensic anthropological literature have found an association between femoral axis length and estimation of sex and ancestry. This is due to the great variability in the proximal femur. Studies of Femoral Axis length and Hip axis length by DEXA can, in African, Asian and European populations and among male and female showed significant variation and were seen to be predictor of sex and ancestry. Unlike hip axis length there were no associations found between greater femoral axis length and fracture risks (Meeusen, Christensen, & Hefner, 2015), (Villette, Zhang, Phillips, & mechanobiology, 2019).

1.17 Intertrochanteric Length

Intertrochanteric region of femur is the area distal to the neck of femur and proximal to shaft. It comprises of greater trochanter and lesser trochanter communicating to each other through intertrochanteric line. Fractures of intertrochanteric region are very common in elderly population. These are defined as extracapsular fractures occurring between the both trochanters. This region is composed of dense trabecular bone. Both trochanters provide an area for attachment of important muscles of thigh that are responsible for gait stability and different types of movements. Greater trochanter provides attachment to the muscles of the gluteal region such as gluteus minimus, maximus, piriformis and obturator internus. Lesser trochanter provides attachment to the tendons of psoas major and iliacus muscle. Calcar femorale (Figure-9)is a dense vertical wall which originates from posteromedial portion of femoral shaft and ends at posterior portion of femoral neck. This anatomical landmark is important to see that whether a fracture is stable or not. The intertrochanteric region unlike the head and neck of femur has abundant vascular supply and has a higher union rate (Attum & Pilson, 2021). Common fixation devices used in intertrochanteric fractures is cephalomedullary nails, which are either short or long devices. Longer and newer generation nails have minimized the postoperative complications (Sadeghi, Prentice, Okike, & Paxton, 2020),.

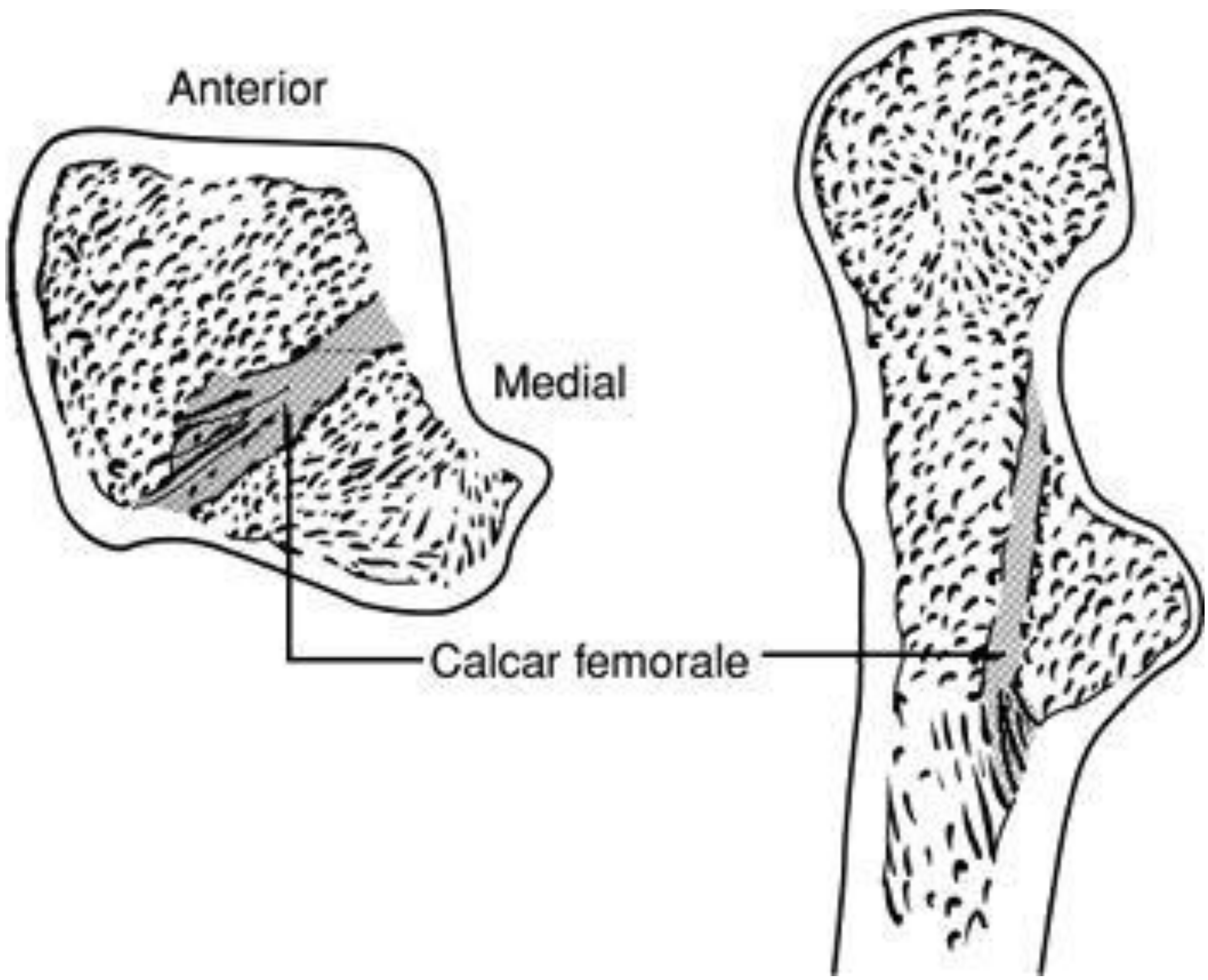


Figure-9: Schematic diagram showing bony architecture of proximal femur highlighting calcar femorale, an anatomical landmark for fracture (Koval & Zuckerman, 2000).

1.18 Medial and vertical offsets

Femoral head offset or medial offset is a horizontal distance from the femoral head center to the femoral shaft axis line while vertical offset is distance from the femoral head center to the lesser trochanter (Verma et al., 2017).

The accuracy of these distances plays a significant role in the range of motion and strength of abductor muscles in total hip replacement surgeries. The result of quality of life can be influenced by changing the offset in hemiarthroplasty. Vertical offset can easily be evaluated in plain X-rays of hip before performing any surgical approach but horizontal offset is influenced by different factors such as lower extremity rotation implant insertion technique and version of hip prosthesis (Rai et al., 2021).

1.19 Clinical significance of proximal femur measurements

More than 80,000 total hip arthroplasties are done worldwide annually. Regional and racial differences are found, so implants need to be designed according to that population. Studies highlight that mismatched and inaccurately fit implants result in micromotion leading to postoperative major complications such as thigh pain, destruction of periprosthetic bone tissue and aseptic loosening. Large implants lead to bone fracture while smaller and undersized prosthesis fail to bond with the bone (Nihat & Meric, 2017), (Verma et al., 2017).

1.20 HYPOTHESIS

1.20.1 Null hypothesis

There are no anatomical morphological differences of the proximal femur geometry among different ethnic groups

1.20.2 Alternate hypothesis

There are anatomical morphological differences of proximal femur geometry among different ethnic groups

1.21 OBJECTIVES OF STUDY:

- To compare the differences in proximal femur geometry of right and left femur
- To compare the differences in proximal femur geometry among male and female
- To compare differences among different ethnic groups
- To study associations of proximal femur geometry with BMI, lifestyle factors and comorbidities

1.22 STATEMENT OF THE PROBLEM

Anatomical variations can be present in most individuals and implants are designed and manufactured according to data and morphology of the western world which may vary from that of Pakistani population

1.23 SIGNIFICANCE OF STUDY

Evaluation of Proximal femur geometry, measurement of head, neck, neck length, intertrochanteric length and neck shaft angle or mikulicz angle. It is important in the measurement for the evaluation of hip biomechanics. There is involvement of proximal femur in different diseases such as developmental hip dysplasia, congenital coxa Vera, fibrous dysplasia of hip. Changes in proximal femur geometry alter the biomechanics and alter the gait of patient. Measurements of proximal femur are important in orthopedic surgeries such as those involving neck of femur, inter-trochanteric fractures, and total hip arthroplasty.

1.24 OPERATIONAL DEFINITIONS

1.24.1 Proximal femur:

Proximal femur is the area that includes the femoral head, neck and the region 5-cm distal to the lesser trochanter (Eyüboğlu et al.,2020)

1.24.2 Femoral neck shaft angle (NSA):

The NSA is the measurement of the angle formed between the obliquely placed femoral neck with the vertically placed shaft and is an essential anatomic measurement for the assessment of hip biomechanics (Pathak et al, 2016)

1.24.3 Femoral neck:

The femoral neck appears at an angle from shaft of femur relative to the terminal end of femoral condyles (Hans et al, 2010)

1.24.4 Proximal femoral fracture:

Proximal femoral fractures are a group of fractures occurring in the hip region which are more common in elderly population and patients with osteoporosis (Emmerson, 2020)

1.24.5 Hip fracture:

A hip fracture is a break in the continuity of femoral bone which is common in the elderly and has a high risk of early mortality (Nijmeijer et al, 2016)

1.24.6 Trochanteric Fracture:

Trochanteric fractures include the fractures of proximal femur in between the shaft and cervical region (Adam, 2014)

1.24.7 Fibrous dysplasia of hip:

Fibrous dysplasia is an uncommon and benign fibrous bone tumor which is present in younger population mostly (Yung et al, 2018)

CHAPTER 2

LITERATURE REVIEW

An in-depth understanding regarding anatomy of proximal femur is needed as basis to know the treatment options for fracture of proximal femur. These include the development, morphology, muscles and ligamentous insertions to it. Fractures of femur are common and have a significant morbidity, mortality and a huge socioeconomic burden, affecting elderly population and particularly old aged women. The epidemiology varies from country to country and is variable in different ethnic groups. The expected risk of hip fracture in US is 17.5% in women and 6% in men. The number of fractures in 1990 were 1.26 million which are expected to increase by 4.5 million in 2050. Great socioeconomic burden is due to prolonged hospitalization and subsequent rehabilitation resulting in development of outcomes such as disability, psychological disorders and cardiovascular diseases (Konda, 2018; Veronese & Maggi, 2018).

Fracture of hip is one of the major health problems. Estimation of cases is necessary to properly manage and have a plan for reducing the burden on healthcare system. There are multiple factors involved in pathogenesis of fracture which can be grossly categorized into diseases involving the bone mineral density leading to osteoporosis and those related to high energy trauma. Factors related to bone mineral density are modifiable and non-modifiable changes. The modifiable changes leading to fractures are low dietary calcium intake, preventable inflammatory diseases, decreased sunlight exposure leading to reduced Vitamin-D, use of osteoporosis causing medication, excessive alcohol consumption, and unbalanced diet. The unmodifiable changes include genetic factors contributing to osteoporosis, family history of bone diseases, gender differences, and advanced age. Elder people are more susceptible to fractures from low energy fall. The factors affecting bone and leading to osteoporosis is increasing due to new dietary habits such as smoking, alcohol consumption and use of soft drinks in our daily food (Chen, Liu, Zhao, & Shi, 2020).

Urbanization of countries have changed the dietary forms of people from nutritional drinks to non-nutritional and carbonated beverages during past few decades. This evolution has increased the incidence of chronic bone diseases. A Chinese survey for examining nutritional and health status of Chinese was conducted which found significant association between fracture and modern dietary patterns (Melaku et al., 2017). One of the main components of recent global dietary change is excessive use of soft drinks with food, gaining popularity among young individuals. This change has increased the risks of diabetes, obesity and cardiovascular diseases to a greater extent (Pacheco et al., 2020). Use of soft drinks leads to decreased consumption of healthy drinks such as milk which negatively effects the intake of beneficial elements like magnesium and calcium causing the bones weak, brittle and more prone to bone diseases and fracture. Studies show an association between soft carbonated drinks intake and teenage fractures. Carbonated drinks decrease the accumulation of minerals in bone and leads to lower bone mineral density and fracture (Chen et al., 2020).

A direct association is seen between bone mineral density (BMD) and smoking. The link was earlier thought to be only associated with elderly women but now the studies show that smoking is involved in low BMD in male population older than 50 years. Independently to routine activities, smoking leads to hip bone fractures by lowering BMD. Major contributor to low bone density is genetics, few non changeable causes like old age and changeable causes include dietary habits and smoking. Likelihood of BMD loss in advancing age is linked to chemical ingredients of cigarette; cadmium and nicotine have a negative effect on bone cells by decreasing the Vit. D and calcium absorption. Along with changes in Vit. D and calcium levels, smoking also alters hormonal levels of estrogen in body leading to bone mineral density loss and fracture. A study by HHS (U.S department of health and human services) showed lower levels of BMD in menopausal females. A decrease in BMD is seen in smokers by 2% every year and by the age of 80 years a distinction of 6%. A study on association between smoking and BMD showed that smoker men had a more negative effect than women. Research links smoking in younger age with reduced peak bone mass and differed bone density and morphology. Study on Belgian health population concluded that individuals who started smoking at an early age from 16 years and earlier, had a reduced BMD as compared with non-smokers. Moreover, a research on Swedish male population also showed similar results, a research was conducted on 1000 young males who showed decreased BMD of whole body, trochanters, proximal femur and neck of femur compared with the control group of non-smokers. The mean study duration was 4.1 years which concludes that bone changes occur early in smokers (Hernigou & Schuind, 2019).

Femur or the thigh bone is a long bone of skeleton which is the longest and strongest. They bear the most of body load and help in mobility. The proximal end has head, neck and two projections, the greater trochanter and lesser trochanter providing attachment for muscles of thigh. The head is spherical in shape and fits inside the acetabulum forming a ball and socket joint. A pit for ligament of head is seen on the medial surface of head. The neck joins the shaft with the head. It is cylindrical in shape pointing slightly forward and superomedially. It forms an angle which is variable in between gender and becomes variable with age, decreasing from infancy to adulthood. The neck is attached with shaft which has two tubercles, the greater trochanter and lesser trochanter (Drake, Vogl, Mitchell, Tibbitts, & Richardson, 2020).

At the junction of neck and shaft a tubercle extends superiorly and laterally called the greater trochanter. On the medial surface of greater trochanter is a deep depression, the trochanteric fossa providing attachment to a flat triangular muscle, the obturator externus. On the anterolateral surface and lateral surface, it provides attachment to gluteus minimus and medius respectively. On the medial surface just above the trochanteric fossa is an impression for the attachment of obturator internus and gemelli muscles.

The lesser trochanter is smaller than the greater trochanter, it is a conical eminence with variable size just inferior at the base of neck. It provides attachment to two important muscles, the iliopsoas (iliacus and psoas major muscles). Intertrochanteric line is a line present obliquely on the interior surface of the femur that originates from the base of greater trochanter and ends on the base of lesser trochanter. Intertrochanteric crest like the intertrochanteric line is a bony ridge on the posterior surface that originates from the posterior margin of greater trochanter and ends at base of lesser trochanter.

The femoral shaft descends from lateral to medial direction at an angle of 7º in coronal plane and brings the knees closer to body and makes it more stable. Thus, the distal part of femur becomes closer to midline than the proximal end. The proximal end of shaft is wide and becomes narrow and more cylindrical towards middle. The middle portion is cylindrical and triangular in shape with three borders and three surfaces, the anterior, posteromedial and posterolateral surfaces. The posterior margin becomes wide and becomes rough elevated crest known as Linea aspera. On the posterior surface another line or small ridge emerges from the lesser trochanter and joins the intertrochanteric line called pectineal line. It provides attachment to pectineus muscle. On the base of greater trochanter, a linear roughening or so-called third tuberosity is seen. It provides attachment to an important muscle of thigh, the gluteus maximus muscle, the main extensor muscle of the hip (Drake et al., 2020).

Although femur being the longest and strongest bone in the body is still commonly fractured bone. The fractures are commonly age and sex related. Common fractures of femur include fracture of neck because it is the weakest and narrowest part of bone and bears body weight. Diseases such as osteoporosis with increasing age and female gender make the bone more susceptible to fractures. Proximal femur fractures occur at different levels, common are subcapital neck fracture, transcervical neck fracture, intertrochanteric and subtrochanteric fractures. Transcervical and intertrochanteric fractures (Figure-10) occurs mostly due to indirect trauma. Due to inclination angle these fractures are unstable. Overriding of fractures and muscular spasm of this region leads to shortening of limbs. Trauma to proximal femur sometime leads to interruption of blood supply to the bone and leads to avascular necrosis of femoral head or osteonecrosis (Matthews & Stitson, 2020).

Greater trochanter and shaft fractures commonly occur due to high energy trauma or from direct hit during road traffic accidents and while playing sports, common in young age. A spiral fracture sometimes leads to Segmental fracture and breaks the bone to different pieces. The fragments override due to muscular pull and leading to shortening of leg and leg length discrepancy**.** Depending on fracture type and size healing and union of bone may take from months to a year. Distal femur fractures can be complicated with fracture involving the condyle separation changing the normal alignment of knee. Fracture of condyles may rupture the popliteal artery, one of the major arteries of leg running behind it and may result into hemorrhage and compromising the supply to important muscles of leg (Moore & Dalley, 2018).

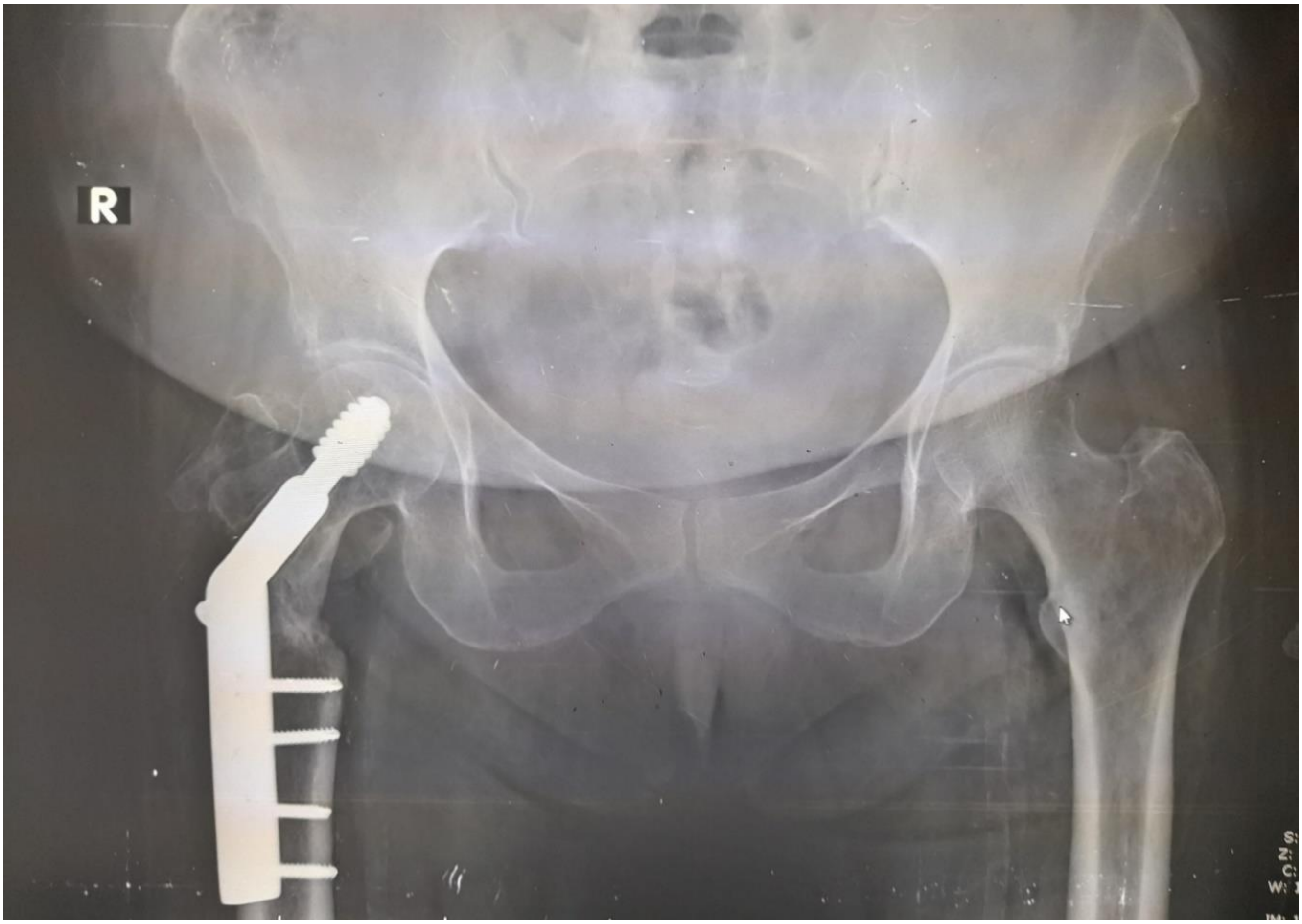


Figure-10. Anteroposterior female Hip radiograph showing intertrochanteric fracture fixed with sliding hip screw system. A large Lag screw is seen in the femoral head and 4 cortical screws in shaft.

Femoral neck shaft angle or femoral angle of inclination is angle formed between femoral neck and long shaft of femur. This angle varies with age being widest in infancy and reduced with time, it is also variable in sex and femur development. Coxa vara is a condition in which the angle is decreased than normal while coxa valga is an increase in inclination angle of femur. The term valga describes a bone or joint that is deformed and deviated from midline (Moore & Dalley, 2018).

High energy trauma causes femoral shaft fractures, such as injuries from motor vehicle collision, car accidents and fall from over speeding motor bikes unless a pathological fracture such as from osteoporosis making the bone weak and brittle and metastatic bone disease. Injuries are often associated to knee, pelvis and hip along with other body parts. The degree of force applied defines the severity of fracture. The fractures are either closed or open, oblique, transverse or spiral fractures. In USA, the frequency of fractures of femur are reported to be 1-1.33 among 10,000 people every year. The incidence becomes 2 in 100,00 in children. In early age before 25 years and in elderly population more than 65 years of age, the incidence of fracture is 3 in 10,000 individuals per year. Due to increase in average life span and increased number of elderly populations the incidence of fracture is continuously increasing. Low BMD in old age is the main reason to higher incidence of proximal femur fracture. Although there is strong association between low BMD and fracture but many hips fracture predictors are independent of bone mineral density. Study shows incidence of hip fracture to be 17 times more in 15% of female with risk factors more than 5 not including BMD compared with 47% of female with 2 or lesser risk factors. If the patient had lower BMD and risk factors more than 5 then risk of fracture was even greater (Sheehan, Shyu, Weaver, Sodickson, & Khurana, 2015).

Femoral fracture risk is associated with several factors. Fracture incidence increases in individuals over 70 years of age. Older age hip fractures are common with higher incidence of intracapsular and extracapsular fractures (Table-1). Patients of bone diseases such as osteoporosis are more prone to femoral fracture. Female to male ratio is higher, twice than male in Europe and America due to increased bone loss and increased number of falls than males. Moreover, female life span is more than male so more than ¾ of proximal femoral fractures occur in females (Sheehan, Shyu, Weaver, Sodickson, & Khurana, 2015).

General Anatomic Classification of Hip Fracture

FRACTURE TYPE	*FREQUENCY*	*POTENTIAL COMPLICATIONS*
Intracapsular fracture		
Femoral neck	45 percent in the elderly; male-to-female ratio: 1:3	Avascular necrosis of the femoral head, nonunion or malunion, late degenerative changes
Extracapsular fracture		
Intertrochanteric	45 percent in the elderly; male-to-female ratio: 1:3	Rarely, nonunion or malunion; degenerative changes
Subtrochanteric	10 percent, with bimodal distribution (i.e., persons 20 to 40 years of age and persons more than 60 years of age)	High rates of nonunion and implant (i.e., intramedullary nails or devices); fatigue because of high physical stresses in the region

Table- 1. Classification of hip fractures according to their anatomical position.

(Brunner, Eshilin-Oates, & Kuo, 2003)

Classification of fractures according to severity are

Type 1: Hairline or stress fracture

Type 2: Severe impacted fracture

Type 3: Incomplete or partial fracture

Type 4: complete displaced fracture

Type 1: (Stress Fracture)

This type of fracture is a tiny crack in the bone. This occurs due to overuse of bone while playing sports, jumping repeatedly and running for a long distance affecting mostly the weight bearing bones. Repeated use of muscles makes them overtired and decreases the shock absorbing capacity of the muscle and stress is transmitted to the bones which results in small cracks in the bones

Type 2: (Severe Impaction Fractures)

It is a complex type of fracture in which the bone breaks into multiple fragments. One fragment goes into another. This type usually occurs when significant amount of force is applied on bone from both ends, leading to split of bone into two or more fragments driven into one another.

Type 3: (Partial Fracture)

This type of fracture is partial break of bone. the bone breaks but does not involve the entire width. Usually seen in children in which a break is seen on one side and a bend on the other side.

Type 4: (Complete Displaced Fracture)

This type of fracture is complete displacement of bone into two or more fragments which are no longer in alignment and a gap forms where the bone breaks.

Femoral head injuries are almost always associated with hip injuries and dislocation. It is a rare injury, occurs mostly due to high energy trauma from motor vehicle accidents. Femoral head injuries were firstly described by John Birkett in 1869 (Shaikh, Desai, Kantanavar, & Shah, 2021). Classified on the basis of basic proximal femur fractures is shown in (Figure-11). Stewart and Milford in 1954 classified the dislocation of hip into four grades; dislocation with fracture of head or neck of femur was classified as grade-IV fracture (Mandell et al., 2017). Pipkin in 1957 further subclassified the grade IV fracture of Stewart and Milford called pipkin classification. It was based on a study of 24 patients and 25 hip fractures among which 22 were from road traffic collisions. Pipkin classified the hip fractures into 4 types.

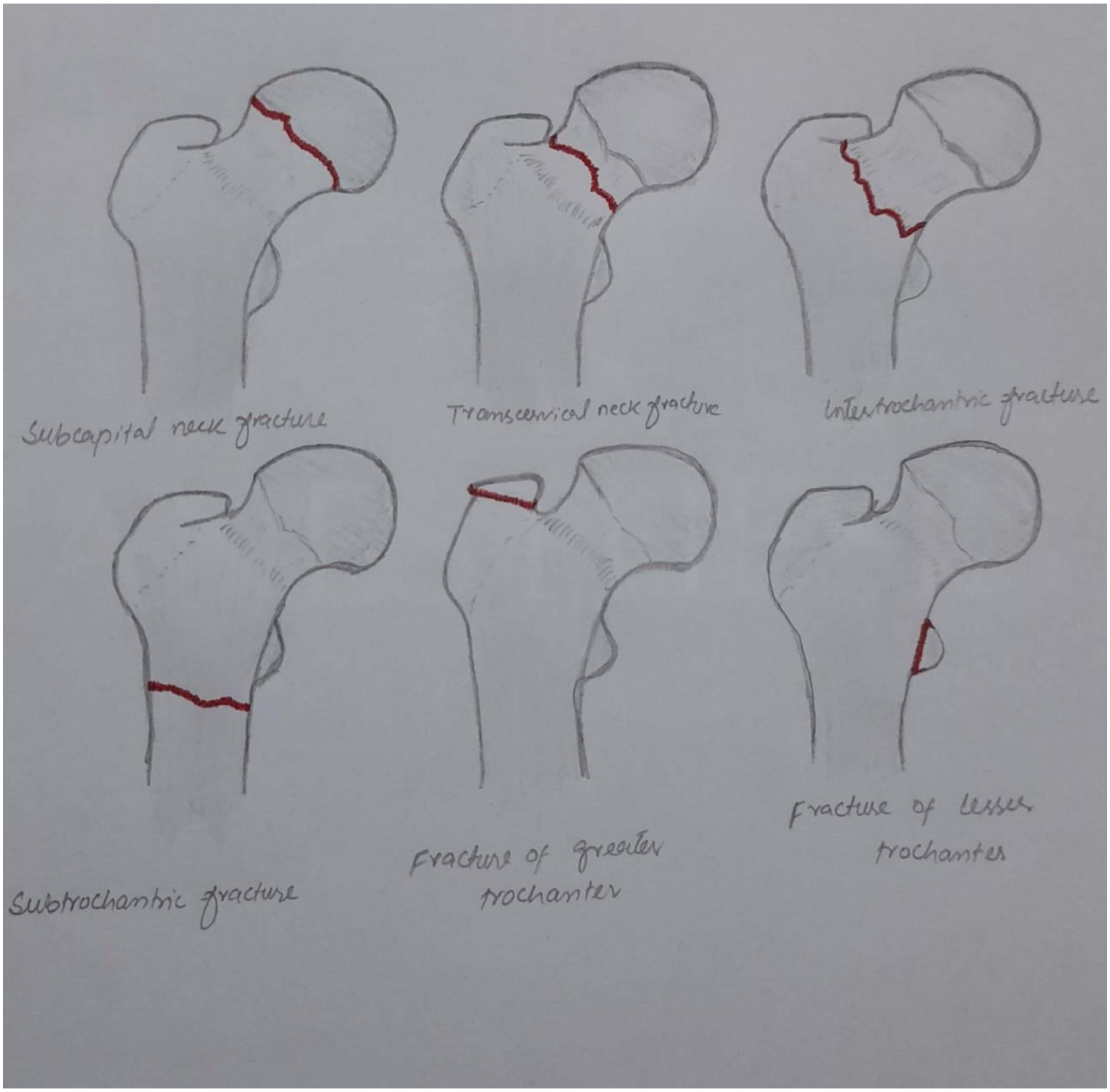
Type I: Hip dislocation involving femoral head fracture inferior to fovea capitis femoris.

Type II: Hip dislocation and femoral head fracture superior to fovea capitis femoris.

Type III: Type 1 or Type 2 with femoral neck fracture associated with it.

Type IV: Type 1 or Type 2 with acetabular fracture associated with it (Romeo, Firoozabadi, & research, 2018; Sheehan et al., 2015).

Pipkin classification is based on taking fovea capitis femoris as point of reference as due to the presence of ligamentum teres. In type 2 fracture, the ligamentum teres is attached to the broken fragment which often rotates the fragment and can complicate the concentric reduction of the broken piece. This type of fracture minimizes the chances of closed reduction and need to be corrected by open reduction and internal fixation. Type 1 fractures are much easier with a higher success rate and can be fixed by closed means



only. In Type 3 fractures, closed management can be possible but neck component needs significant force which may not be possible in closed reduction. Type 4 fracture is managed primarily with closed reduction but acetabular rib component needs to be managed with open reduction and fixation (Romeo et al., 2018).

Figure-11. Basic proximal femur fracture types. Different combination of these fractures can occur (Brunner et al., 2003)

Hip fracture patients are at a higher risk of morbidity, mortality and decreased quality of life. Treatment options are variable depending on patient's age, built, type of fracture, location and configuration of fracture. The primary goal is to restore the patient mobility. Early hip surgery within 48 hours of admission is associated with greater outcomes (Emmerson, Varacallo, & Inman, 2021). Surgical options include hemiarthroplasty, in which half of the hip is replaced. It includes the femoral head replacement with an implant. Total hip arthroplasty (THA) includes replacement of femoral head with a ball like, and the acetabulum with a cup like prostheses. Total hip arthroplasty is seen to be superior than hemiarthroplasty and is recommended for management of displaced femoral neck fractures in patients with 80 years or younger with life expectancy of more than 4 years. (Lewis, Wæver, Thorninger, & Donnelly, 2019). Studies suggest that patients with more physical activity THA have better outcomes. In a comparison of THA with HA, THA has higher degree of instability but better functional outcomes (Guyen, Surgery, & Research, 2019; Medicine, 2019).

Study shows that average femoral head diameter in female patients is 48.3 mm and in males is 55.8 mm (Ernest Y. Young, Jeremy Gebhart, Daniel Cooperman, & Nicholas U. Ahn, 2013). Most frequently used bearing sizes in THA range from 32-36 mm diameter heads prosthesis. Better stability and significant daily activities were performed with more than 32 mm head prosthesis as compared with 26mm heads, while no functional benefits were seen with use of prosthesis more than 36 mm diameter heads (Tsikandylakis et al., 2018). Other factors taken in account for longevity of prosthesis depend upon implant design, gender, fracture type, lifestyle, surgical procedure and experience of surgeon (Cohen, Kogan, Rubin, Zimran, & Lebel, 2020).

The mean femoral neck diameter (FND) in a study was found to be 39.3 mm in males and 33.7 mm in females (Jamali et al., 2013). In another study the mean FND was 36.6 and 36.4 in Caucasian and African-Americans respectively {Young, 2013

#181}Average mean value of FND in Indian population was 29.5 (Siwach, 2018). The average FND in Chinese population is 38.75 mm in males and 33.39 mm in females (Hu, Liu, & Zhang, 2018). Femoral neck has significantly reduced periosteal thickness as compared to diaphyseal bone. With increasing age it is more reduced and leads to weaker bone. Multiple logistic regression analysis showed that increased FND decreases the incidence of intertrochanteric fractures. Thickness of lower cortex in femoral neck hardly changes. Changes in upper cortex are seen with age which bears a large impact in case of lateral fall and causes fracture of neck. Males have a greater FND as compared with females, it might be a reason behind higher incidence of femoral neck fractures in females. Knowing average values of FND is great value as it is a vital geometrical parameter in surgeries of hip especially in internal fixation of neck fractures and total hip arthroplasty. Neck diameter also helps the surgeon in selection of proper screws for internal fixation and puncture direction for fixation (Hu et al., 2018).

In a comparison of femoral neck fracture with intertrochanteric fractures, femoral neck axial length (FNAL) was found to be more in intertrochanteric fracture group. From the view of biomechanics, the lengthier neck of femur causes more protrusion of greater trochanter thus causing increased risk of intertrochanteric fractures. Association between longer axial length and greater risk of intertrochanteric fracture is documented by several researchers. It is a vital geometrical parameter in open reduction internal fixation in hip fractures and total hip replacement surgeries. It is of vital clinical importance in restoring the normal hip anatomy after fractures. The normal FNAL in Chinese population is 101.44 mm, in males the mean value is 107.47 mm whereas in female the value is 99.59 mm (Hu et al., 2018).

Hip axial length (HAL) is the measurement of FNAL with the hip joint space and acetabular wall. Gender and ethnic differences are found in HAL length. Strong association between longer HAL and hip fracture is seen. In females there is an increase in HAL during early puberty while becomes lesser in mid puberty. Unlike female there is increase in HAL throughout puberty in males. At maturity males have a longer HAL than female. Association between height and HAL is seen but no association between weight is seen. Most importantly there is strong association between different ethnic group especially in between females of different ethnicities (Wang et al., 1997). A study on Chinese population shows smaller HAL than European population and concluded that it may be one of the reasons of lower fracture incidences in this population. Normal HAL in Chinese population is 127.53 in males and 116.51 in females (Hu et al., 2018). In a study on comparison of normal and hip fracture group in Canadian population the mean value was observed to be 104.7 mm in non-fracture and 106.9 mm in fracture group showing significant association between longer HAL and hip fracture (Leslie et al., 2015).

X-ray hip is considered to be first line of investigation in acute hip pain and suspected proximal femur fractures. They have a sensitivity of 93-98%. Routinely used X-ray hip includes anteroposterior view and lateral views. Frog leg view radiographs are usually not recommended in cases of proximal femur fracture as they can further displace the fracture. AP view along with lateral view is advised in cases of subtrochanteric fractures to see the extension of the fracture. In cases of occult femoral neck fractures which are 2-10%, Magnetic resonance imaging (MRI) with sensitivity of 99-100% is suggested as second line if accessible within 24 hours. Bone scan and computed tomography (CT) scan is considered as third line. MRI is advised in patients with age more than 50 years and with bone osteoporotic changes. Fracture in MRI appears as bone marrow edema surrounded by T1 hypointense line. Early diagnosis and surgery reduce lengthening of hospital stay and better postoperative results with lesser morbidity and mortality rates. The ultimate goal of surgery is to allow the patient restore mobilization and weight bearing (Kani, Porrino, Mulcahy, & Chew, 2019).

CHAPTER 3

METHODOLOGY

3.1 STUDY DESIGN

Cross sectional study

3.2 ETHICAL APPROVAL

The study was approved by the ethical review committee and faculty research committee of the Bahria University Medical and Dental College. It was also approved by the ethical review committee of the PNS Shifa hospital Karachi.

3.3 SETTING

The study was conducted in the Department of Radiology PNS Shifa hospital Karachi.

3.4 INCLUSION CRITERIA

- Age between 20 to 70 years
- Patients undergoing X-ray for acute hip pain other than fracture
- X-ray KUB (Kidney ureter Bladder) with visible proximal femur
- X-ray hip for any gynecological reasons
- Radiographs of Abdomen
- Provided written informed consent

3.5 EXCLUSION CRITERIA

- Patients with history of fracture of femur or hip bone

- Patients with hip dysplasia, osteoarthritis, rheumatoid arthritis or any other bone disease
- Patients with previous Hip surgery
- Patients with any bone deformity
  - Subjects with implants
  - Pregnant women
  - Individuals under the age of 20 years and over the age of 70 years

3.6 DURATION OF STUDY:

(a) Individual study period: approximately 2 hours

(b) Total period of study: 6 months after approval of synopsis

3.7 SAMPLE SIZE CALCULATION:

Sample Size for Frequency in a Population

Population size (for finite population correction factor or fpc) (*N*):	1000000
Hypothesized % frequency of outcome factor in the population (*p*):	4.5%+/-5
Confidence limits as % of 100(absolute +/- %) (*d*):	5%
Design effect (for cluster surveys-*DEFF*):	1

Sample Size(*n*) for Various Confidence Levels

Confidence	Level (%)	Sample Size
95%		67
80%		29
90%		47
97%		81
99%		115
99.9%		187
99.99%		261

Equation

Sample size $n = [DEFF*Np(1-p)]/ [(d^2/Z^2_{1-\alpha/2}*(N-1) +p*(1-p)]$

The sample size calculation in this study was by (OpenEpi, Version 3, open source calculator—SSPropor) and it was found to be minimum 67 subjects.

3.8 SAMPLING TECHNIQUE:

The sampling technique used was non-probability convenient sampling.

3.9 HUMAN SUBJECTS AND CONSENT:

The participants were recruited from referred patients from different OPDs and emergency department, presenting to the radiology department for X-ray hip, pelvis and abdomen. After informed consent, 70 individuals between 20-70 years were enrolled in the study. Anteroposterior radiographs of both hips were used for measurements. The X-ray was done using Fujifilm Digital Radiography Madrex 500. The images were transferred via the Agfa Fuji archiving and communication system (PACS) for measurements and study.

3.10 MATERIALS:

3.10.1 Subject Evaluation form

Patient's personal information regarding the demographics like age, gender and patient's personal characteristics such as presenting complaint, symptom duration and lifestyle factors containing smoking and frequency of soft drink use were asked at the time of history taking in the reception room of the department of radiology PNS Shifa and were noted in the subject's evaluation form.

3.10.2 Informed consent form:

After explaining in detail, the risk and significance of participation in the study, an informed consent form was filled and signed by the participant.

3.10.3 Portable Stadiometer

Height of subjects was measured by portable stadiometer in out-patient departments and emergency department and measurements were recorded in the patient's evaluation form.

3.10.4 BMI Calculation:

The BMI was calculated by dividing weight in kilograms with the square of height in meters using the formula;

weight (Kg)/ height (m^2)

The BMI cut-off points were classified into following categories as severely underweight, underweight, normal weight, overweight, obese class I , obese class II and obese class III (Weir & Jan, 2019).

• Severely underweight - BMI less than 16.5kg/m^2 • Underweight - BMI under 18.5 kg/m^2 • Normal weight - BMI greater than or equal to 18.5 to 24.9 kg/m^2 • Overweight – BMI greater than or equal to 25 to 29.9 kg/m^2
• Obesity – BMI greater than or equal to 30 kg/m^2 o Obesity class I – BMI 30 to 34.9 kg/m^2 o Obesity class II – BMI 35 to 39.9 kg/m^2 o Obesity class III – BMI greater than or equal to 40 kg/m^2 (Also referred to as severe, extreme, or massive obesity)
• Asian and South Asian population o Overweight - BMI between 23 and 24.9 kg/m^2 o Obesity - BMI greater than 25 kg/m^2

3.10.6 Fujifilm Digital Radiography Madrex 500 and PACS system

Radiographs were taken in Anteroposterior view via Fujifilm digital X-ray machine. Radiographs were sent to Picture archiving and communication system (PACS) for measurements. All parameters of proximal femur were measured by using synapse radiology software, an image intelligence Fujifilm technology used worldwide for fast and high-quality imaging. The standard dosage for x-ray pelvis was set to be 0.7 mSv (Günalp et al., 2014)

3.11 PARAMETERS OF STUDY

The parameters or characteristics of studied population were divided into four categories i.e., demographics, proximal femur measurements, personal parameters and lifestyle factors. The demographics of the patients included age, gender and ethnicity. The proximal femur measurements included the measurements of femoral head diameter, femoral neck diameter, neck shaft angle, neck length, intertrochanteric length, medial offset, vertical offset, femoral axis length and hip axis length. Personal parameters included height, weight, BMI, presenting complaint, symptom duration and frequency. The lifestyle factors included occupation, exercise, use of hip equipment.

3.12 PROTOCOL OF STUDY

Patients referred to department of radiology PNS Shifa hospital for X-ray Hip/Pelvis, X-ray Abdomen and X-ray KUB for the assessment and management of the diseases of hip, abdomen, kidney or any other gynecological issue, were told about the study and were asked to sign an informed consent form. The risks and benefits of the study were told and it was made sure that they understood the procedure. The radiographs were taken by the same X-ray machine. They were then evaluated for the measurement of proximal femur by the principal investigator and were cross checked by an expert radiologist.

Measurements were done on software Synapse PACS system by using ruler for measurements of diameter and length. Angle option was used for measurement of femoral neck shaft angle.

3.12.1 Positioning of the Patient

An anteroposterior hip radiograph was positioned as patient lying in supine position on the x-ray table. Arms were at the side or crossed over upper chest with X-ray beam pointing in the middle at the symphysis pubis and a cross line at anterior-superior iliac spine. The distance between the film and the X-ray tube was kept at 120 mm. For accommodation of femoral anteversion, the foot and leg were rotated 15 – 20 degrees internally (Lim, Park, & pelvis, 2015).

3.12.2 Radiographic Image Evaluation

Measurements of X-ray hip anteroposterior view was done on PACS system. All measurements were evaluated and recorded in the patient proforma. For measurement of femoral head diameter, (FHD) a line was drawn from maximum superior edge to the most inferior edge in the equatorial center of the femoral head (Figure-05). Femoral neck diameter (FND) measurement was from the shortest distance from the femoral neck outer superior edge to lateral cortex of medial and inferior margin (Hu, Liu, & Zhang, 2018). Neck shaft angle (NSA) was measured at the junction of two lines, line 1 drawn from the middle of head through femoral neck axis and line 2 from femoral long axis (Boese et al., 2016). (Fig-05)

Femoral neck length (FNL) was measured as the distance between the femoral head base and the intertrochanteric line at the junction of shaft with the neck (Isaac et al., 1997).

Intertrochanteric length (IL) was the length measured from greater trochanter to the lesser trochanter of femur (Hernandez-de Sosa et al., 2016).

Medial offset or (MO) femoral offset was measurement of a perpendicular line drawn from the center of femoral head to a long axis of femur (Bolink et al., 2019).

Vertical offset (VO) was measured by drawing a line in vertical axis from the center of femoral head to the lesser trochanter (Hsieh, Howell, Hull, & Surgery, 2020).

Femoral axis length (FAL) was measurement of line drawn between edge of femoral head and extremities of the greater trochanter in a sagittal plane (figure-12) ((Nihat & Meric, 2017).

Hip axis length (HAL) was measured from base of lateral part of greater trochanter to the inner pelvic rim in longitudinal plane (Figure-12) (Katchy, Njeze, Ezeofor, & Nnamani, 2019).

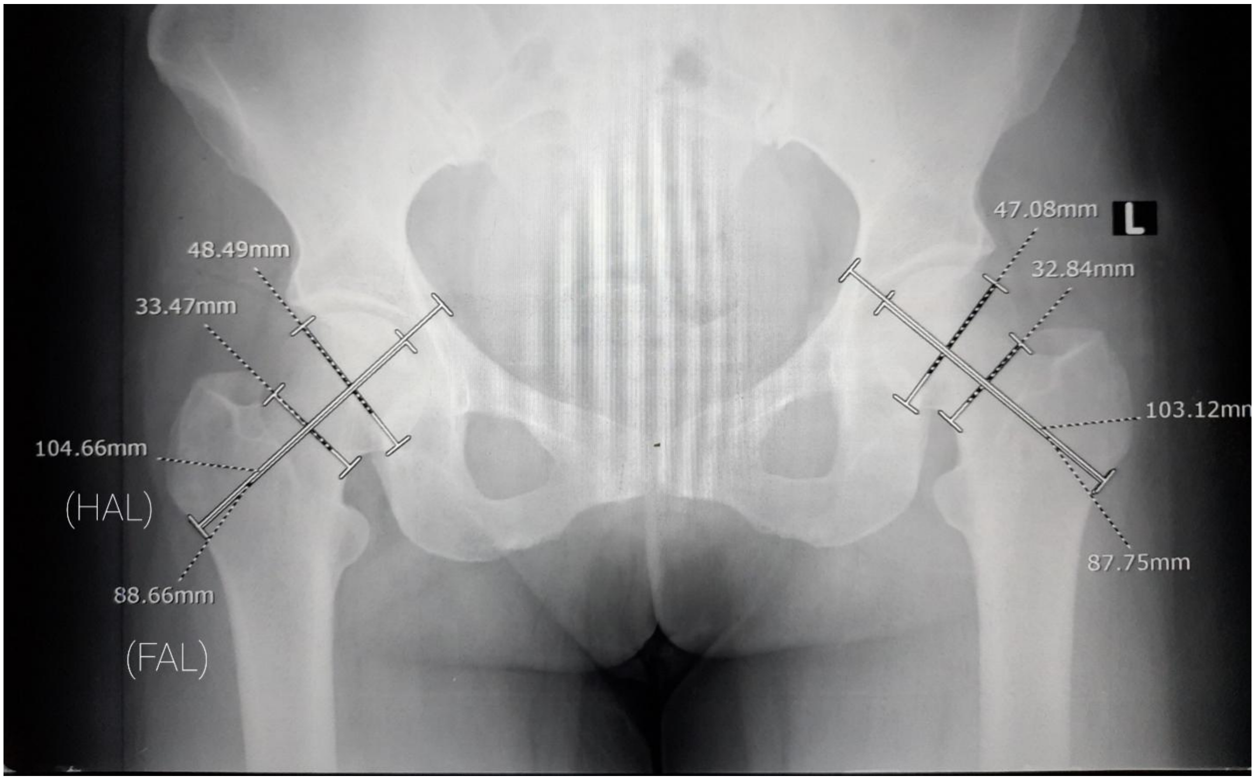
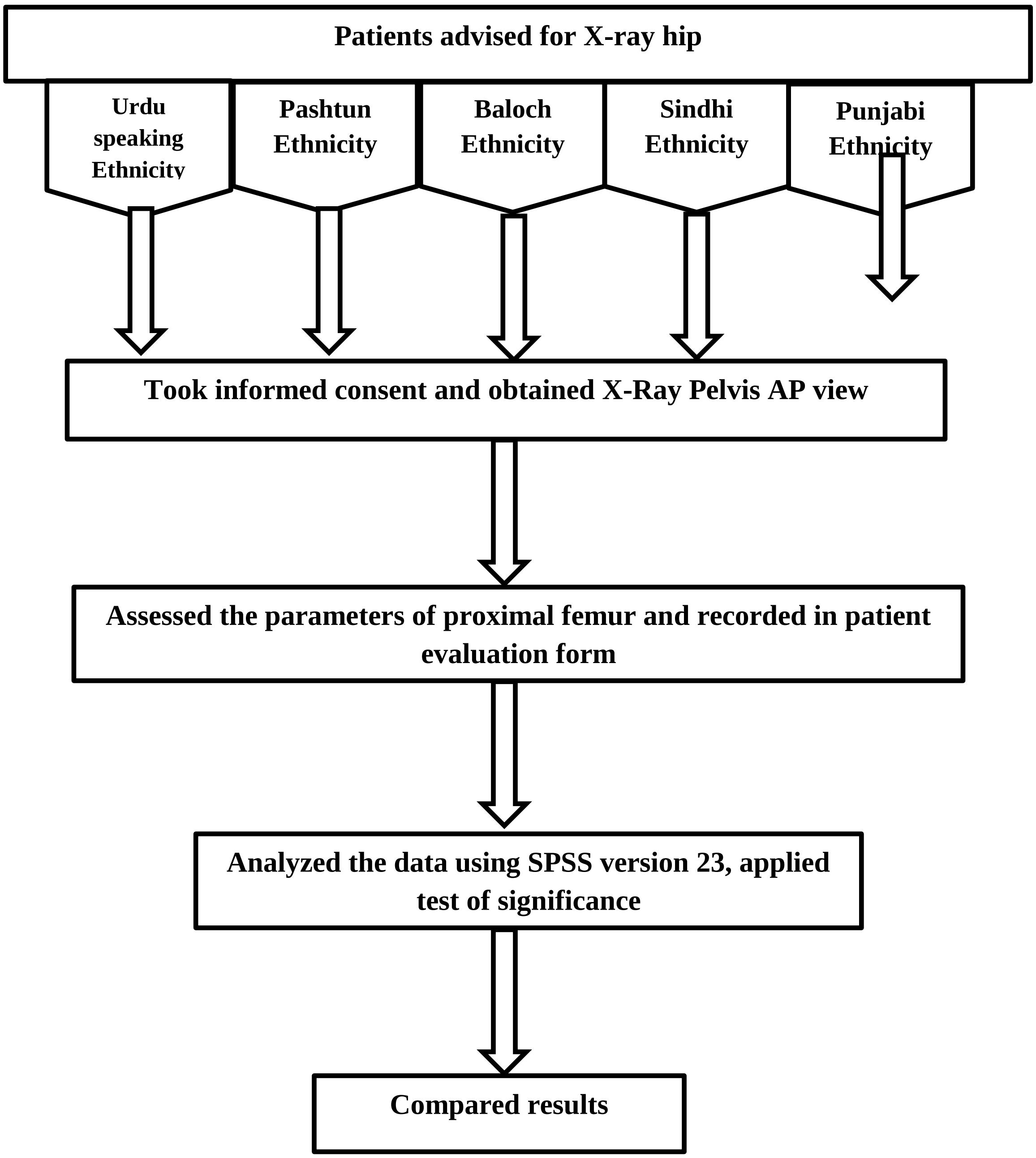


Figure-13: X-ray hip anteroposterior view showing measurements of Hip axis length (HAL) and femoral axis length (FAL)

3.13 ALGORITHM OF STUDY



3.14 STATISTICAL ANALYSIS

SPSS version 23.0 was used for statistical analysis The continuous variables were presented as mean and standard deviation. The categorical variables were presented as frequency and percentage. The data was checked for normality via Histogram with normal curve. Chi-square test and Fisher exact test was applied to find the association between the two categorical variables. For comparison between male and female, independent sample T-test was applied. For comparison of results among different ethnic groups, one-way ANOVA was used. The p-value ≤ 0.05 was considered as a statistically significant difference.

CHAPTER 4

RESULTS

This study was designed to compare differences of proximal femur parameters between male and female gender, right and left, different age groups and most importantly between 5 ethnic groups of Pakistan and to note any variations. Total number of 75 patients were included in the study with 40 males and 35 females (Figure-14). Number of married patients were 54 (Figure-15). The results were plotted in form of tables and graphical representations.

4.1 COMPARISON OF FEMORAL HEAD DIAMETER BETWEEN GENDER

Mean value of femoral head diameter (HD) in males was 52.95±2.58mm and females was 45.96±3.08mm. There was highly significant difference between male and female femoral head diameter. The p-value was 0.000. Mean HD of right femur in males and females were 53.05±2.82mm and 46.00±3.18mm respectively. Mean HD of left femur in males and females were 52.86±2.34mm and 45.92±3.02mm respectively. The p-value of male right HD and female right HD in comparison with male left HD and female left HD was 0.000 (Table-1).

4.2 COMPARISON OF FEMORAL NECK DIAMETER BETWEEN GENDER

The mean value for femoral neck diameter (FND) in male was 38.03±3.63mm and in female was 31.99±2.65mm and this was statistically significant (p-value = 0.000). Mean FND in right male and right female was 38.36±3.50mm and 31.85±2.18mm respectively. The mean value for left FND between male and female was 37.70±3.77mm and 32.14±3.08mm respectively. The p-value comparing between male right with female right and male left with female left was statistically significant with a p-vale 0.000. (Table-2)

4.3 COMPARISON OF FEMORAL NECK LENGTH BETWEEN GENDER

The mean femoral neck length (FNL) in male was 53.10±7.96mm and in female was 45.82±6.41mm. The male FNL in comparison with female was greater with a p-value 0.000. The mean right FNL in male and female was 51.81±7.92mm and 45.56±6.23mm. The mean left FNL in male and female was 54.39±7.86mm and 45.09±6.67mm respectively. The p-value comparing male right FNL with female right FNL and male left FNL with female left FNL was statistically significant with a p-vale 0.000. (Table-3).

4.4 COMPARISON OF FEMORAL INTERTROCHANTERIC LENTH BETWEEN GENDER

The obtained mean value of femoral intertrochanteric length in males and females was 68.93±5.29mm and 61.19±4.79mm respectively. There is statistically significant difference in male and female (p-value = 0.000). Mean values of right intertrochanteric length in males were compared with corresponding values on right side in females which were found to be 69.12±5.30mm and 61.67±4.52mm respectively, while values of left side of males compared with females, the results were 68.73±5.35mm and 60.72±5.07mm respectively. Thus, significant difference was observed between the genders on both right and left side (p-value = 0.000). (Table-4).

4.5 COMPARISON OF FEMORAL MEDIAL OFFSET BETWEEN GENDER

Mean of the values of femoral medial offset in males was 39.67±7.98mm. The mean value in females was 34.53±6.94mm. Significant gender differences were observed with p-value of 0.000. The mean right medial offset in males and females were 37.97±7.54mm and 33.82±6.85mm respectively. Statistically significant difference was seen (p-value = 0.015). The mean values for left medial offset in males and females were 41.37±8.14mm and 35.25±7.06mm respectively. p-value for left of both genders was statistically significant (p-value = 0.001). (Table-5)

4.6 COMPARISON OF FEMORAL VERTICAL OFFSET IN BETWEEN GENDER

The mean femoral vertical offset value in males and females was 61.82±8.39mm and 49.02±8.18mm respectively. Statistically highly significant difference was observed between both genders with p-value 0.000. Values for right side of male and female were

61.299±8.43mm and 48.77±7.25mm respectively (p-value = 0.000). Values for left side in both genders were 62.34±8.42mm and 49.26±9.12mm respectively. p-value was found to be 0.000. Values of vertical offset of left femur were greater compared with the right femur. (Table-6)

4.7 COMPARISON OF FEMORAL NECK AXIS LENGTH BETWEEN GENDER

The mean value observed for male and female femoral axis length (FNAL): were 108.78±7.16mm and 94.47±7.04mm respectively. The p-value was statistically highly significant with value of 0.000. The mean values of male right FNAL and female right FNAL were 108.30±6.99mm and 95.01±6.32mm respectively. p-value was observed to be 0.000. The difference between male left FNAL and female left FNAL were 109.26±7.39mm and 93.92±7.74mm respectively, with highly significance p-value (0.000). (Table-7).

4.8 COMPARISON OF FEMORAL HIP AXIS LENGTH BETWEEN GENDER

The mean hip axis length (HAL) in males and females was 126.46±8.19mm and 106.21±9.28mm respectively. p-value was statistically significant (0.000). The values for right HAL in males and females were 126.61±8.05mm and 106.39±7.84mm respectively with p-value 0.000. The values for left HAL in male and female were 126.31±8.44mm and 106.04±10.65mm respectively with p-value 0.000. (Table-8)

4.9 COMPARISON OF NECK SHAFT ANGLE BETWEEN GENDER

The mean value of femoral neck shaft angle (NSA) in males was 132.23±5.544º and females was 132.085±6.597º. There were insignificant differences of NSA between genders, the p-value was 0.928. NSA of Right femur in males was 133.025±5.83º and mean value of right NSA in females was 132.714±5.97º and p value was 0.950. The mean NSA value of left male femur was 131.450±5.1885º and that of female left femur was 131.4571±7.1962º with p value 0.272 (Table-9).

4.10 COMPARISON OF RIGHT AND LEFT FEMORAL HEAD DIAMETER BETWEEN ETHNIC GROUPS

Mean Right femoral Head diameter for all 5 ethnic groups (Figure-16) was 49.72±4.62mm. Mean values of HD in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 50.27±4.73mm, 49.99±4.98mm, 49.25±4.79mm, 51.58±4.40mm and 48.20±4.04mm respectively. No statistically significant differences of right HD were seen between ethnic group (p-value = 0.405). The mean value for Left HD in all ethnicities was 49.62±4.38mm. In Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking the values were 49.86±3.97mm, 49.78±5.05mm, 49.30±4.28mm, 51.45±4.60mm and 48.07±3.89mm respectively. No statistically significant differences were observed between the Left HD of ethnic groups (p-value = 0.389). (Table-10).

4.11 COMPARISON OF RIGHT AND LEFT FEMORAL NECK DIAMETER BETWEEN ETHNIC GROUPS

Comparison of ND showed a mean value of 35.32±4.40mm in all 5 ethnic groups. Mean values for Right ND in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 35.32±3.58mm, 36.08±4.12mm, 34.78±3.93mm, 37.56±5.44mm and 33.34±4.44mm respectively. No statistically significant differences were observed between the Right ND of ethnic groups (p-value = 0.136). The mean value for Left ND in all ethnicities was 35.11±4.43mm. In Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking the values were 34.57±3.53mm, 35.97±4.26mm, 34.60±4.05mm, 37.96±5.19mm and 32.86±4.07mm respectively. Statistically significant differences were observed between the Left ND of ethnic groups (p-value = 0.036) (Table- 11).

4.12 COMPARISON OF RIGHT AND LEFT FEMORAL NECK LENGTH BETWEEN ETHNIC GROUPS

In this study the mean value of neck length in left femur was observed to be greater than the right femur. Mean Values for right proximal femur was observed to be 48.89±7.79mm. In 5 different ethnic groups the values for right FNL were observed to be in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking as 51.66±6.37mm, 50.26±4.92mm, 49.65±8.05mm, 44.93±9.14mm and 47.64±8.83mm respectively. The differences in right femoral neck length were statistically nonsignificant with a p-value of 0.210. In left femur the mean FNL was observed to be 50.51±8.40mm, while in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking the values were 52.31±3.86mm, 52.60±8.49mm, 51.12±8.09mm, 48.10±9.91mm and 48.19±10.04mm respectively. The differences in left femoral neck length were statistically nonsignificant with a p-value of 0.463. (Table-12)

4.13 COMPARISON OF RIGHT AND LEFT INTERTROCHANTERIC LENGTH BETWEEN ETHNIC GROUPS

Analysis of intertrochanteric length in different ethnic groups showed a mean value of 66.64±6.18mm in right femur (p-value = 0.154) and 64.99±6.56mm in left femur (p-value = 0.419). mean values of intertrochanteric length, observed in right femur of Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 66.17±3.98mm, 66.94±5.66mm, 66.19±7.94mm, 65.43±5.59mm and 63.25±5.69mm respectively. The difference was observed to be statistically nonsignificant with p-value 0.570. In left proximal femur the mean value of IL in 5 ethnic groups was found to be 64.99±6.56mm. In different races such as Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking the values were observed to be 65.21±4.75mm, 67.20±6.62mm, 64.95±7.57mm, 65.29±5.82mm and 62.38±6.77mm respectively. The p-value was observed to be 0.437. (Tablet-13).

4.14 COMPARISON OF RIGHT AND LEFT MEDIAL OFFSET BETWEEN ETHNIC GROUPS

Medial offset of proximal femur was observed in between different populations of Pakistan. The mean medial offset value for right femur in different races was observed to be 36.03±7.48mm while that for left femur was recorded to be larger with a mean value of 38.51±8.20mm. MO of right femur was recorded in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking that was 37.10±6.33mm, 37.80±5.95mm, 36.60±7.65mm, 34.08±10.11mm and 34.29±6.92 respectively. There were no significant correlations between values in medial offset of right femur. The p-value was 0.601. MO of left femur was recorded in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking which was 39.35±4.89mm, 39.76±6.68mm, 39.08±8.47mm, 37.28±11.15mm and 36.81±8.92mm respectively. there was no any significant difference between these ethnic groups (P value = 0.844). (Table-14).

4.15 COMPARISON OF RIGHT AND LEFT VERTICAL OFFSET BETWEEN ETHNIC GROUPS

The average femoral vertical offset of right femur for the entire sample was 55.45±10.06mm and for left femur was 56.24±10.90mm. The right VO in different ethnic groups such as Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 55.10±7.96mm, 59.47±11.70mm, 56.47±10.32mm, 54.13±10.84mm and 51.36±8.09mm respectively. p-value was 0.289. VO of left femur was recorded in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking which was 55.26±8.59mm, 59.18±13.44mm, 57.36±10.64mm, 56.28±11.41mm and 52.33±10.07mm respectively. The p-value was 0.544. (Table-15)

4.16 COMPARISON OF RIGHT AND FEMORAL NECK AXIS LENGTH BETWEEN ETHNIC GROUPS

Findings related to femoral neck axis length showed mean value of right femur in different populations of Pakistan to be 102.10±9.41mm. mean value of left side was found to be 102.10±10.75mm. The right FNAL in different ethnic groups such as Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 103.42±6.01mm, 103.82±9.03mm, 101.66±11.18mm, 101.48±9.54mm and 100.51±9.91mm respectively. p-value was 0.884 which is statistically nonsignificant. Mean values of left FNAL in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 104.22±6.05mm, 103.80±13.34mm, 101.40±10.56mm, 102.90±11.20mm and 98.94±11.57mm respectively. There were no significant correlations between values in FNAL of left femur. The p-value was 0.712. (Table-16).

4.17 COMPARISON OF RIGHT AND LEFT HIP AXIS LENGTH BETWEEN ETHNIC GROUPS

Among the femoral geometry measures, the mean value of right HAL in all groups was observed to be 117.17±12.86mm and for left HAL was 116.85±13.90mm. Mean values of left HAL in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 121.64±9.48mm, 118.02±13.40mm, 117.09±15.13mm, 116.50±12.25mm and 113.25±11.91mm respectively. There were no significant correlations between values in HAL of right femur in different populations. The p-value was 0.595. Mean values of left HAL in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 119.95±9.52mm, 118.50±15.80mm, 117.83±15.14mm, 117.52±14.42mm and 110.38±12.35mm respectively. (p-value = 0.418). (Table-17).

4.18 COMARISION OF RIGHT AND LEFT FEMORAL NECK SHAFT ANGLE BETWEEN ETHNIC GROUPS

Number of patients included in the present study were 75, among whom 29.33% were Punjabi, 18.66% were Pathan, 18.66% were Urdu speaking, 17.33% were Sindhi and 16% were Baloch. Mean femoral neck shaft angle of Right femur for all 5 ethnic groups was 132.88±5.86. Mean values of Right NSA in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 134.25±3.84, 132.71±6.77, 133.09±5.00, 130.07±8.56, and 134.14±4.22 respectively. The value of NSA was highest in Baloch, followed by Urdu speaking, whereas lowest value was observed in Sindhi ethnic group.

A comparison of Sindhi and Urdu speaking showed a significant difference in the right femur with a p-value of 0.039. while an insignificant increase was observed on the left femur with a p-value of 0.209. Comparison of Sindhi with Baloch also showed a significant difference on the right femur with a p-value of 0.042 while on the left side an insignificant increase was observed (p-value 0.351). Comparison of Pashtun with Punjabi showed no significant difference with p-value of 0.849 on right side and 0.801 on left side.

The mean values for Left NSA in Baloch, Pashtun, Punjabi, Sindhi and Urdu speaking were 131.66±4.94, 131.14±8.32, 131.72±5.53, 130.30±7.57 and 132.21±4.62 respectively.

4.19 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL HEAD DIAMETER

Age wise distribution of patients were. Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70 (Figure-17). Number of patients in these groups were 29,12,11,10 and 13 respectively. In group 1-5 the average values of measured right femoral head diameter were 50.52±5.30mm, 51.15±3.27mm, 46.46±2.83m, 50.56±4.74mm and 48.94±4.30mm respectively. No statistical significance was observed between these age group and between the right and left femurs. p-value was 0.081. Mean values of left FHD in group 1-5 were found to be 50.26±4.62mm, 50.52±3.45mm, 46.49±3.08mm, 50.36±5.11mm and 49.43±4.36mm respectively. Differences were nonsignificant with p-value 0.131. (Table-19)

4.20 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK DIAMETER

In this cross-sectional study of 75 patients there was no significant differences of femoral neck diameter. Patients between age group 51-60 had the largest FND. Patients were distributed in 5 age groups Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70. The average value of right femur in these groups were 35.48±4.09mm, 36.58±3.59mm, 32.51±3.55mm, 36.62±6.18mm and 35.17±4.36mm respectively. (p-value = 0.171). Mean values of left FND in group 1-5 were found to be 34.61±3.97mm, 35.80±3.47mm, 32.21±2.90mm, 37.13±6.35mm and 36.46±4.67mm respectively. (p-value = 0.066). (Table-20)

4.21 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK LENGTH

The patients were categorized into 5 groups according to age. Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70. Number of patients in these groups were 29,12,11,10 and 13 respectively. FNL of right femur in group 1-5 was observed to be 50.21±8.27mm, 48.70±6.55mm, 46.93±6.40mm, 50.18±9.52mm and 46.79±7.70mm respectively. p-value was found to be 0.610. Mean value of left femur were observed to be 51.75±8.96mm, 51.04±6.57mm, 46.05±6.47mm, 53.37±8.81mm and 48.85±9.13mm respectively. p-value was 0.246. (Table-21)

4.22 AGE WISE RIGHT AND LEFT COMPARISON OF INTERTROCHANTRIC LENGTH

Distribution of patients were in 5 different age groups. Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70. The mean right intertrochanteric length in all age groups was 65.64±6.18mm while on left side it was found to be 64.99±6.56mm. IL was found to be largest in patients with age group between 51 and 60. The mean right IL values in all five age groups from 1-5 were found to be 66.73±6.37mm, 66.06±4.99mm, 62.01±6.59mm, 67.80±8.08mm and 64.25±3.43mm respectively. Differences between age groups were statistically nonsignificant with p-value 0.154. The mean left IL values in all five age groups from 1-5 were found to be 65.45±6.30mm, 65.53±5.79mm, 61.61±7.89mm, 66.88±8.26mm and 64.89±4.99mm respectively. Differences between age groups were statistically nonsignificant with p-value 0.419. (Table-22)

4.23 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL MEDIAL OFFSET

Medial offset of proximal femur was observed in between different age groups to see if there were any significant differences among them. No any significant differences were found. p-value for MO of right and left femur were 0.832 and 0.467 respectively. Age group were Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70 years. The mean right MO in these groups were found to be 35.87±8.95mm, 34.74±5.03mm, 34.85±4.30mm, 37.61±8.50mm and 37.39±7.62mm respectively. The mean left MO in these groups were found to be 38.22±9.44mm, 38.62±6.57mm, 35.18±5.69mm, 41.84±8.45mm and 39.33±8.15mm respectively. (Table-23).

4.24 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL VERTICAL OFFSET

Geometrical evaluation of 75 hip x-rays showed mean values of right femoral offset in different groups to be 55.45±10.06mm while that of left side was observed to be 56.24±10.90mm. patients were distributed into 5 groups age ranging from 20-70 years. Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70 years. Mean values of VO for right femur of these groups were

59.45±9.34mm, 56.58±9.04mm, 48.24±9.34mm, 55.38±10.92mm and 51.64±8.93mm respectively. The differences were observed to be statistically significant with p-value 0.012. Mean values of VO for left femur of these groups were 60.49±10.07mm, 57.00±9.43mm, 50.69±11.08mm, 57.30±11.21mm and 49.91±10.05mm respectively. Statistically significant values were observed between these groups. p-value was observed to be 0.015. (Table-24).

4.25 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK AXIS LENGTH

Femoral neck axis was measurement of straight distance from the greater trochanteric base to femoral head apex. Mean values in different age groups for right and left side were observed to be 102.10±9.41mm and 102.10±10.75mm respectively. Division of groups according to age were Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70 years. Mean values for right FNAL of these groups were 103.21±9.21mm, 105.28±8.38mm, 97.36±8.27mm, 105.11±11.28mm and 98.38±8.68mm respectively. (p-value = 0.103). Mean values for left FNAL of these groups were 104.25±10.46mm, 105.50±9.11mm, 94.94±8.30mm, 105.22±11.62mm and 97.83±11.19mm respectively. Difference between age groups of left FNAL was found to be statistically significant with p-value 0.034. (Table-25)

4.26 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL HIP AXIS LENGTH

The 75 patients evaluated for HAL included 29 patients age ranging from 20-30 years (Group-1), 12 patients with age ranging from 31-40 years (Group-2), 11 patients age ranging from 41-50 years (Group-3), 10 patients with age between 51-60 years (Group-4) and 13 patients from elderly population with age ranging from 61-70 years. Mean HAL values of right hip in these 5-age group were measured to be 119.39±11.78mm, 122.43±11.11mm, 107.83±11.60mm, 119.93±16.95mm and 113.14±10.62mm respectively. p-value was observed to be statistically significant with 0.030. Mean HAL values for left hip were observed to be 120.81±13.23mm, 121.94±12.79mm, 105.90±9.41mm, 118.21±15.74mm and 111.53±12.95mm respectively. p-value was observed to be statistically significant 0.030 (Table-26)

4.27 AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK SHAFT ANGLE

The current study involved 75 patients with age ranging from 20-70 years. Patients were divided into 5 age groups. Group-1 from 20-30, Group-2 from 31-40, Group-3 from 41-50, Group-4 from 51-60 and Group-5 from 61-70. The mean NSA between right and left femur of these age groups were 132.88±5.86º and 131.45±6.16º. The left NSA in all age groups was found to be smaller than the right NSA. NSA was found to be inversely associated to age. Increase in age showed a decrease in NSA. Mean value of right NSA of group 1-5 showed 135.24±6.53, 134.08±2.31, 132.72±3.84, 131.40±5.12 and 127.76±5.50 degrees respectively. Comparison of right NSA between these age groups showed significant differences (p-value 0.002). Mean values of left NSA of group 1-5 were observed to be 134.24±5.87, 132.41±3.62, 132.18±3.70, 128.70±5.33 and 125.84±6.95 degrees respectively. Statistically significant differences were observed between these age groups p-value was observed to be 0.000. (Table-27).

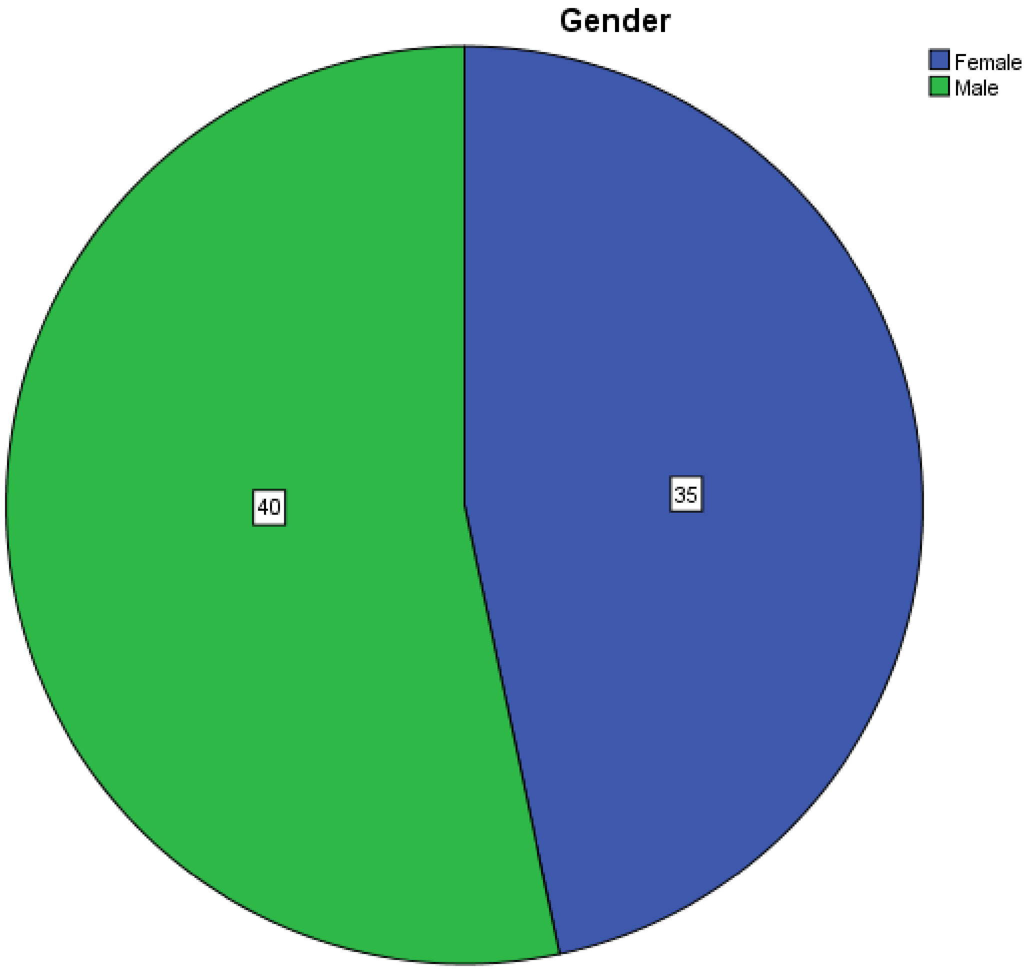


Figure- 14: Pie chart showing male and female cases included in the study

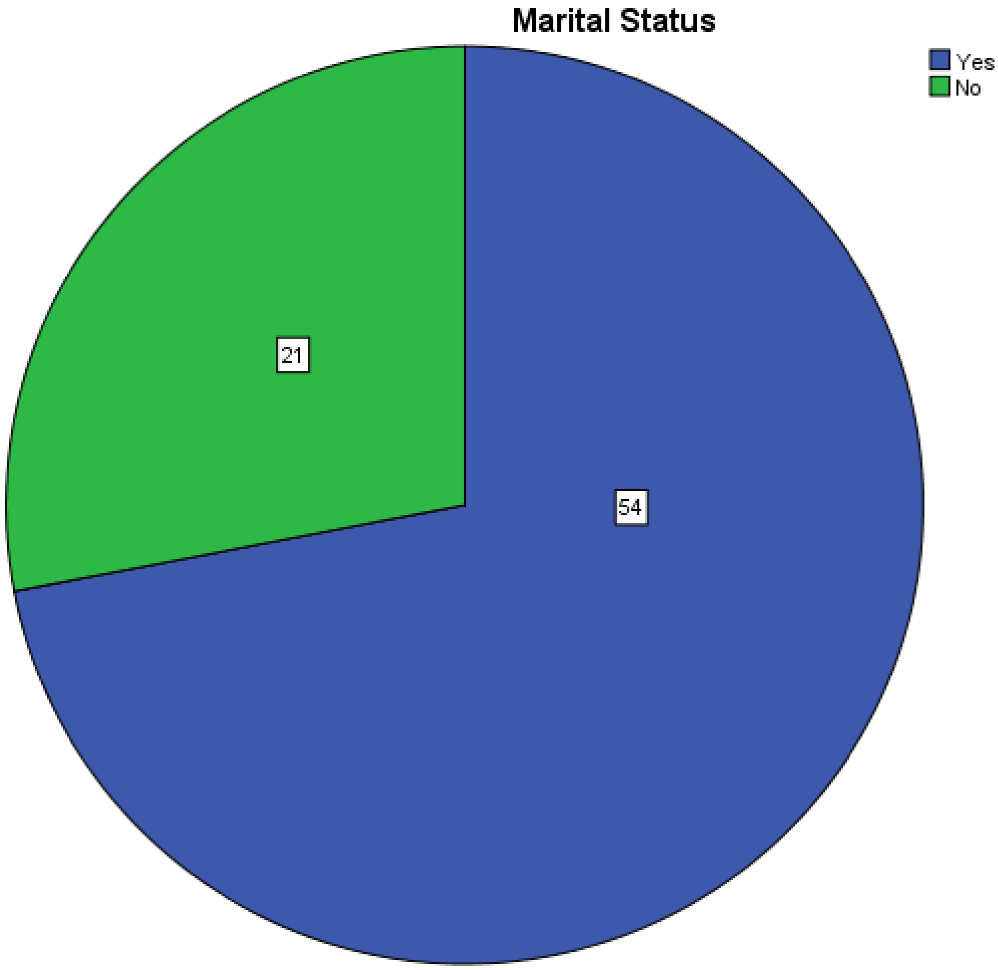


Figure-15: Pie chart showing marital status of patients included in the study

Table-2

COMPARISON OF FEMORAL HEAD DIAMETER BETWEEN GENDER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
FHD (mm)	Male	40	52.95±2.58	0.000**
	Female	35	45.96±3.08	
Right FHD (mm)	Male	40	53.05±2.82	0.000**
	Female	35	46.00±3.18	
Left FHD (mm)	Male	40	52.86±2.34	0.000**
	Female	35	45.92±3.02	

FHD: Femoral head diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-3

COMPARISON OF FEMORAL NECK DIAMETER BETWEEN GENDER

n = 75

Parameter	**Gender**	**n**	**Mean ± SD**	**p-value**
FND (mm)	Male	40	38.03±3.63	0.000*
	Female	35	31.99±2.65	
Right FND (mm)	Male	40	38.36±3.50	0.000*
	Female	35	31.85±2.18	
Left FND (mm)	Male	40	37.70±3.77	0.000*
	Female	35	32.14±3.08	

FND: Femoral neck diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-4

COMPARISON OF FEMORAL NECK LENGTH BETWEEN GENTER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
FNL (mm)	Male	40	53.10±7.96	0.000**
	Female	35	45.82±6.41	
Right FNL (mm)	Male	40	51.81±7.92	0.000**
	Female	35	45.56±6.23	
Left FNL (mm)	Male	40	54.39±7.86	0.000**
	Female	35	45.09±6.67	

FNL: Femoral neck length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-5

COMPARISON OF FEMORAL INTERTROCHANTRIC LENTH BETWEEN GENTER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
IL (mm)	Male	40	68.93±5.29	0.000**
	Female	35	61.19±4.79	
Right IL (mm)	Male	40	69.12±5.30	0.000**
	Female	35	61.67±4.52	
Left IL (mm)	Male	40	68.73±5.35	0.000**
	Female	35	60.72±5.07	

IL: Intertrochanteric length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-6

COMPARISON OF FEMORAL MEDIAL OFFSET BETWEEN GENDER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
MO (mm)	Male	40	39.67±7.98	0.000**
	Female	35	34.53±6.94	
Right MO (mm)	Male	40	37.97±7.54	0.015*
	Female	35	33.82±6.85	
Left MO (mm)	Male	40	41.37±8.14	0.001**
	Female	35	35.25±7.06	

MO: Medial Offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-7

COMPARISON OF FEMORAL VERTICAL OFFSET IN BETWEEN GENDER

n = 75

Parameter	**Gender**	**n**	**Mean ± SD**	**p-value**
FVO (mm)	Male	40	61.82±8.39	0.000**
	Female	35	49.02±8.18	
Right FVO (mm)	Male	40	61.299±8.43	0.000**
	Female	35	48.77±7.25	
Left FVO (mm)	Male	40	62.34±8.42	0.000**
	Female	35	49.26±9.12	

FVO: Femoral vertical offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-8

COMPARISON OF FEMORAL NECK AXIS LENGTH BETWEEN GENDER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
FNAL (mm)	Male	40	108.78±7.16	0.000**
	Female	35	94.47±7.04	
Right FNAL (mm)	Male	40	108.30±6.99	0.000**
	Female	35	95.01±6.32	
Left FNAL (mm)	Male	40	109.26±7.39	0.000**
	Female	35	93.92±7.74	

FNAL: Femoral neck axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-9

COMPARISON OF FEMORAL HIP AXIS LENGTH BETWEEN GENDER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
HAL (mm)	Male	40	126.46±8.19	0.000**
	Female	35	106.21±9.28	
Right HAL (mm)	Male	40	126.61±8.05	0.000**
	Female	35	106.39±7.84	
Left HAL (mm)	Male	40	126.31±8.44	0.000**
	Female	35	106.04±10.65	

HAL: Hip axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

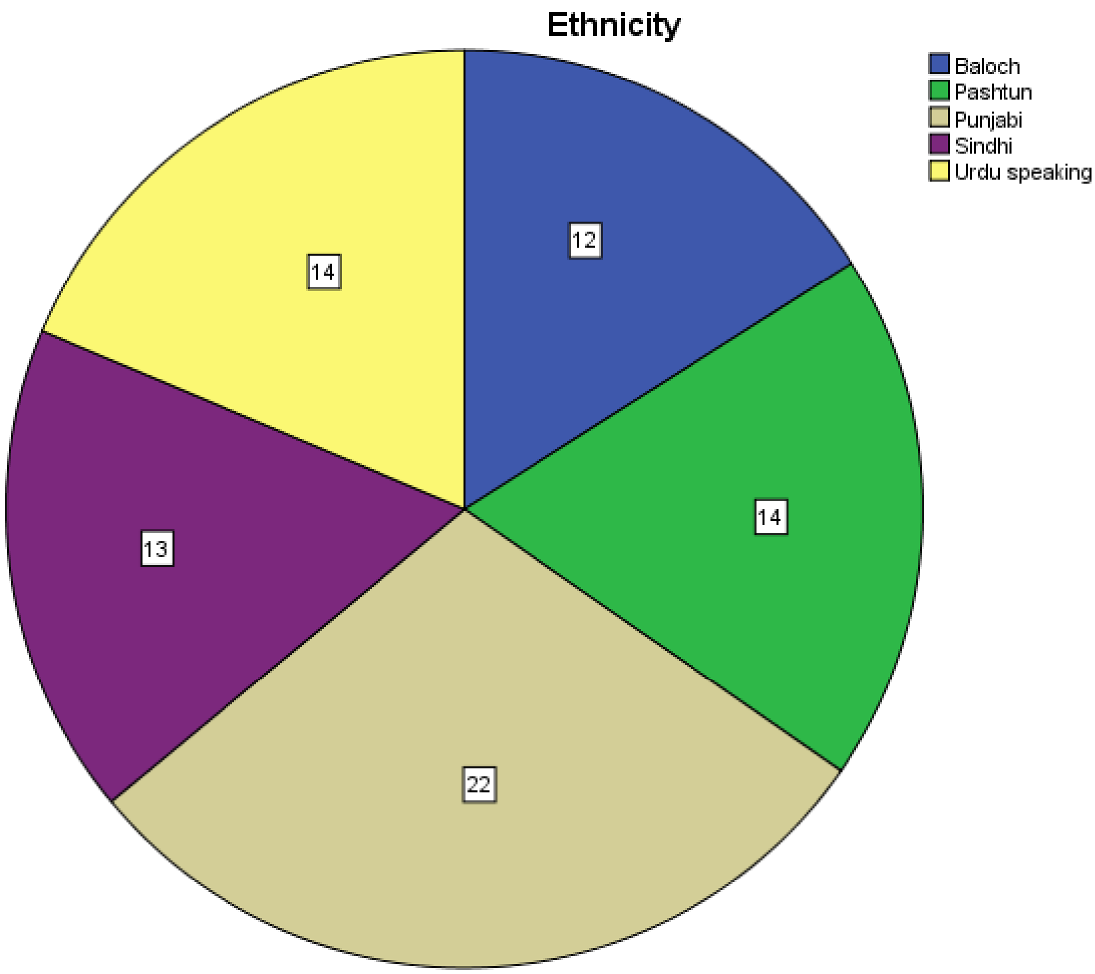


Figure-16: Pie chart showing different ethnic groups who participated in this study

Table-10

COMPARISON OF NECK SHAFT ANGLE BETWEEN GENDER

n = 75

Parameter	Gender	n	Mean ± SD	p-value
NSA (Degrees)	Male	40	132.23±5.54	0.928
	Female	35	132.08±6.59	
Right NSA (Degrees)	Male	40	133.02±5.83	0.950
	Female	35	132.71±5.97	
Left NSA (Degrees)	Male	40	131.45±5.18	0.272
	Female	35	131.45±7.19	

NSA: Neck Shaft Angle

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: Independent-samples t-test

Table-11

COMPARISON OF RIGHT AND LEFT FEMORAL HEAD DIAMETER BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FHD (mm)	Baloch	12	50.27±4.73	0.405	49.86±3.97	0.389
	Pashtun	14	49.99±4.98		49.78±5.05	
	Punjabi	22	49.25±4.79		49.30±4.28	
	Sindhi	13	51.58±4.40		51.45±4.60	
	Urdu speaking	14	48.20±4.04		48.07±3.89	

FHD: Femoral head diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-12

COMPARISON OF RIGHT AND LEFT FEMORAL NECK DIAMETER BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FND (mm)	Baloch	12	35.32±3.58	0.136	34.57±3.53	0.036*
	Pashtun	14	36.08±4.12		35.97±4.26	
	Punjabi	22	34.78±3.93		34.60±4.05	
	Sindhi	13	37.56±5.44		37.96±5.19	
	Urdu speaking	14	33.34±4.44		32.86±4.07	

FND: femoral neck diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-13

COMPARISON OF RIGHT AND LEFT FEMORAL NECK LENGTH BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FNL (mm)	Baloch	12	51.66±6.37	0.210	52.31±3.86	0.463
	Pashtun	14	50.26±4.92		52.60±8.49	
	Punjabi	22	49.65±8.05		51.12±8.09	
	Sindhi	13	44.93±9.14		48.10±9.91	
	Urdu speaking	14	47.64±8.83		48.19±10.04	

FNL: Femoral neck length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-14

COMPARISON OF RIGHT AND LEFT INTERTROCHANTRIC LENGTH BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
IL (mm)	Baloch	12	66.17±3.98	0.570	65.21±4.75	0.437
	Pashtun	14	66.94±5.66		67.20±6.62	
	Punjabi	22	66.19±7.94		64.95±7.57	
	Sindhi	13	65.43±5.59		65.29±5.82	
	Urdu speaking	14	63.25±5.69		62.38±6.77	

IL: Intertrochanteric length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-15

COMPARISON OF RIGHT AND LEFT MEDIAL OFFSET BETWEEN ETHNIC GROUPS

n = 75

Parameter	**Ethnic Groups**	**n**	**Mean ± SD (Rt Side)**	**p-value**	**Mean ± SD (Lt Side)**	**p-value**
MO (mm)	Baloch	12	37.10±6.33	0.601	39.35±4.89	0.844
	Pashtun	14	37.80±5.95		39.76±6.68	
	Punjabi	22	36.60±7.65		39.08±8.47	
	Sindhi	13	34.08±10.11		37.28±11.15	
	Urdu speaking	14	34.29±6.92		36.81±8.92	

MO: Medial offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-16

COMPARISON OF RIGHT AND LEFT VERTICAL OFFSET BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FVO (mm)	Baloch	12	55.10±7.96	0.289	55.26±8.59	0.544
	Pashtun	14	59.47±11.70		59.18±13.44	
	Punjabi	22	56.47±10.32		57.36±10.64	
	Sindhi	13	54.13±10.84		56.28±11.41	
	Urdu speaking	14	51.36±8.09		52.33±10.07	

FVO: Femoral vertical offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-17

COMPARISON OF RIGHT AND FEMORAL NECK AXIS LENGTH BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FNAL (mm)	Baloch	12	103.42±6.01	0.884	104.22±6.05	0.712
	Pashtun	14	103.82±9.03		103.80±13.34	
	Punjabi	22	101.66±11.18		101.40±10.56	
	Sindhi	13	101.48±9.54		102.90±11.20	
	Urdu speaking	14	100.51±9.91		98.94±11.57	

FNAL: Femoral neck axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-18

COMPARISON OF RIGHT AND LEFT HIP AXIS LENGTH BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic Groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
HAL (mm)	Baloch	12	121.64±9.48	0.595	119.95±9.52	0.418
	Pashtun	14	118.02±13.40		118.50±15.80	
	Punjabi	22	117.09±15.13		117.83±15.14	
	Sindhi	13	116.50±12.25		117.52±14.42	
	Urdu speaking	14	113.25±11.91		110.38±12.35	

HAL: Hip axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-19

COMARISION OF RIGHT AND LEFT FEMORAL NECK SHAFT ANGLE BETWEEN ETHNIC GROUPS

n = 75

Parameter	Ethnic groups	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
NSA (mm)	Sindhi	13	129.308±7.04	0.039*	129.538±6.10	0.209
	Urdu speaking	14	134.143±4.22		132.214±4.62	
	Sindhi	13	129.308±7.04	0.042*	129.538±6.10	0.351
	Baloch	12	134.250±3.84		131.667±4.94	
	Pashtun	14	132.714±6.77	0.849	131.143±8.32	0.801
	Punjabi	22	133.091±5.00		131.727±5.53	

NSA: Neck shaft angle

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

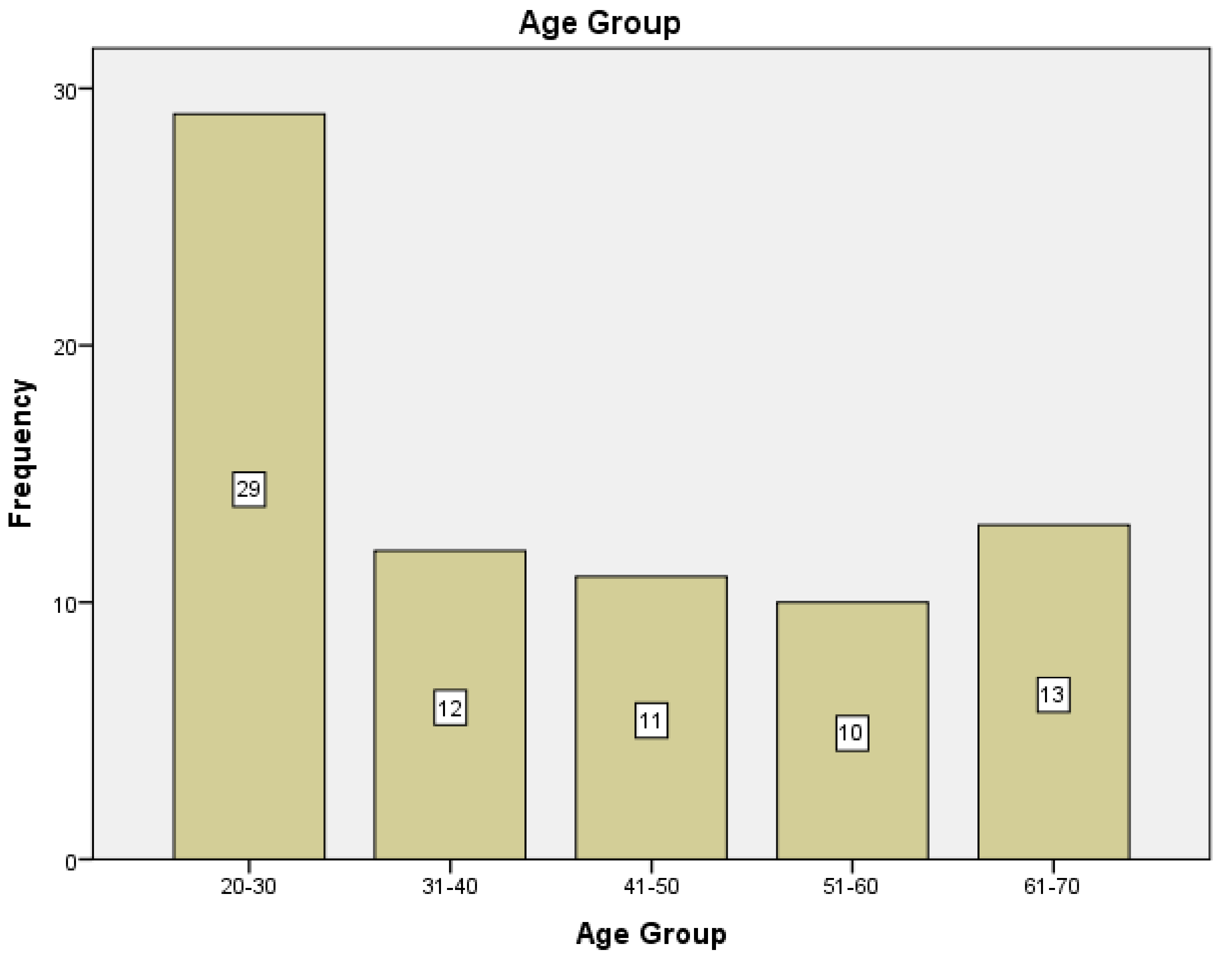


Figure-17: Bar chart showing different age group of patients who participated in the study

Table-20

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL HEAD DIAMETER

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FHD (mm)	20 – 30	29	50.52±5.30	0.081	50.26±4.62	0.131
	31 – 40	12	51.15±3.27		50.52±3.45	
	41 – 50	11	46.46±2.83		46.49±3.08	
	51 – 60	10	50.56±4.74		50.36±5.11	
	61 – 70	13	48.94±4.30		49.43±4.36	

FHD: Femoral head diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-21

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK DIAMETER

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	P-value	Mean ± SD (Lt Side)	p-value
FND (mm)	20 - 30	29	35.48±4.09	0.171	34.61±3.97	0.066
	31 - 40	12	36.58±3.59		35.80±3.47	
	41 - 50	11	32.51±3.55		32.21±2.90	
	51 - 60	10	36.62±6.18		37.13±6.35	
	61 - 70	13	35.17±4.36		36.46±4.67	

FND: Femoral neck diameter

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-22

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK LENGTH

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FNL (mm)	20 – 30	29	50.21±8.27	0.610	51.75±8.96	0.246
	31 – 40	12	48.70±6.55		51.04±6.57	
	41 – 50	11	46.93±6.40		46.05±6.47	
	51 – 60	10	50.18±9.52		53.37±8.81	
	61 – 70	13	46.79±7.70		48.85±9.13	

FNL: Femoral neck length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-23

AGE WISE RIGHT AND LEFT COMPARISON OF INTERTROCHANTRIC LENGTH

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
IL (mm)	20 – 30	29	66.73±6.37	0.154	65.45±6.30	0.419
	31 – 40	12	66.06±4.99		65.53±5.79	
	41 – 50	11	62.01±6.59		61.61±7.89	
	51 – 60	10	67.80±8.08		66.88±8.26	
	61 – 70	13	64.25±3.43		64.89±4.99	

IL: Intertrochanteric length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-24

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL MEDIAL OFFSET

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
MO (mm)	20 – 30	29	35.87±8.95	0.832	38.22±9.44	0.467
	31 – 40	12	34.74±5.03		38.62±6.57	
	41 – 50	11	34.85±4.30		35.18±5.69	
	51 – 60	10	37.61±8.50		41.84±8.45	
	61 – 70	13	37.39±7.62		39.33±8.15	

MO: Medial offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-25

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL VERTICAL OFFSET

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FVO (mm)	20 – 30	29	59.45±9.34	0.012*	60.49±10.07	0.015*
	31 – 40	12	56.58±9.04		57.00±9.43	
	41 – 50	11	48.24±9.34		50.69±11.08	
	51 – 60	10	55.38±10.92		57.30±11.21	
	61 – 70	13	51.64±8.93		49.91±10.05	

FVO: Femoral vertical offset

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-26

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK AXIS LENGTH

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
FNAL (mm)	20 - 30	29	103.21±9.21	0.103	104.25±10.46	0.034*
	31 - 40	12	105.28±8.38		105.50±9.11	
	41 - 50	11	97.36±8.27		94.94±8.30	
	51 - 60	10	105.11±11.28		105.22±11.62	
	61 - 70	13	98.38±8.68		97.83±11.19	

FNAL: Femoral neck axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-27

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL HIP AXIS LENGTH

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
HAL (mm)	20 - 30	29	119.39±11.78	0.030*	120.81±13.23	0.009*
	31 - 40	12	122.43±11.11		121.94±12.79	
	41 - 50	11	107.83±11.60		105.90±9.41	
	51 - 60	10	119.93±16.95		118.21±15.74	
	61 - 70	13	113.14±10.62		111.53±12.95	

HAL: Hip axis length

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

Table-28

AGE WISE RIGHT AND LEFT COMPARISON OF FEMORAL NECK SHAFT ANGLE

n = 75

Parameter	Age (years)	n	Mean ± SD (Rt Side)	p-value	Mean ± SD (Lt Side)	p-value
NSA (Degrees)	20 – 30	29	135.24±6.53	0.002*	134.24±5.87	0.000**
	31 – 40	12	134.08±2.31		132.41±3.62	
	41 – 50	11	132.72±3.84		132.18±3.70	
	51 – 60	10	131.40±5.12		128.70±5.33	
	61 – 70	13	127.76±5.50		125.84±6.95	

NSA: Neck shaft angle

p-value significant ≤ 0.05*, Highly Significant ≤ 0.001**

Test applied: One-way ANOVA

CHAPTER 5

DISCUSSION

The present study was designed to observe the normal values of femoral head diameter (HD), femoral neck diameter (FND), femoral neck length (FNL), intertrochanteric length (IL), medial offset (MO), femoral vertical offset (FVO), femoral neck axis length (FNAL) and hip axis length (HAL), femoral neck-shaft angle (NSA), between gender, different age groups and 5 major ethnic groups of Pakistan. This was a pioneer study in Pakistan, in which these parameters of the proximal femur were assessed to see any differences between them.

Several previous studies using CT, MRI, and plain radiographs have confirmed variations among different Asian, African, and European populations. Studies on different populations are needed due to the preparation of compatible prostheses used in total and Hemi arthroplasties. These implants are designed according to morphometric data of researched populations, which may vary in different populations. Many implants prepared by American and European manufacturers are according to their community-based data that can suit their population but may vary widely from ours. Mismatched implant leads to several complications, including osteolysis, hip pain, and aseptic loosening (Sobana & Nedunchezhiyan, 2019; Wiese et al., 2020)

In this study, sexual dimorphism in femoral head diameter was seen. Males had a greater FHD in comparison to females. Similar to our results were found in Chinese, Nigerian, and Pakistani populations (Hu, Liu, & Zhang, 2018; Katchy, Njeze, Ezeofor, & Nnamani, 2019; Umer et al., 2010). Contradictory to our results a lesser FHD was found in the Indian and Caucasian population (Pierre, Zurakowski, Nazarian, Hauser-Kara, & Snyder, 2010; Verma et al., 2017). The average BMI in the male Pakistani population was higher than females. Male had a heavily built body leading to greater pressure on the proximal femur which could be a reason for a greater femoral head in males. In this research population, most of the males were sailors and dealt with heavy weight lifting which increases the weight of the trunk and exerts more pressure on the proximal femur. According to Wolff's Law which states that bones adapt according to the weight-bearing load placed on them. It alters bone tissue and remodels it to become stronger (Kameo, Tsubota, & Adachi, 2018). Femoral neck diameter plays a vital role in screw fixation after a femoral neck fracture. Knowing the mean values of FND helps a surgeon know the extent of screw fixation. Improper and fixation to a greater extent can lead to avascular necrosis of the femoral head. If a smaller screw is used, it leads to improper or nonunion of fracture (Kim, Tanaka, Tada, Kanoe, & Shirai, 2015). Our study is similar to a previous study by (Gilligan et al., 2013) who documented that FNSA value of 132.3°,130.8°, 132.5° and 130.5° for Chad, Mali, Senegal, and Sudan respectively. Similar to our results were also found in Iranian, and Chinese populations (Hu, Liu, & Zhang, 2018; Kazemi, Qoreishi, Keipourfard, Minator Sajjadi, & Shokraneh, 2016). Results of female subjects were similar to the Indian and Hong Kong populations. Female FHD differed from Caucasian and Turkish population which may be due to healthier population with greater BMI of America and European population (Nihat & Meric, 2017).

Studies suggest that a longer femoral neck was associated to fracture risk (Kazemi, Qoreishi, Keipourfard, Minator Sajjadi, & Shokraneh, 2016; Keyak, Rossi, Jones, Les, & Skinner, 2001). In our study, femoral neck length in males was found to be higher than the Indian, Chinese, and Croatian populations while no significant difference in FNL was seen in those populations and our female population. A study by (Khan, Nasim, & Hussain, 2019) in Pakistan showed femoral fracture to be the commonest fracture in Pakistan accounting for 38% of all fractures. The Percentage of males and females was 72.9 and 27.1 respectively. The higher femoral neck length could be a contributor to the higher incidence of hip fractures. Contrary to our findings (Pires et al., 2012) found no correlation between FNL and fracture. The median of FNL in that population was 37 in men and 35 in women. A smaller FNL may be the reason for not finding any correlation between FNL and fracture.

The intertrochanteric length measurement was taken by the method proposed by (Yamauchi et al., 2016). Less data regarding intertrochanteric length was found in the literature. This may be due to its less importance while performing surgery. Abundant data regarding intertrochanteric fracture was found. Knowing the intertrochanteric length may help the surgeon for internal fixation which is achieved mainly by sliding hip screw system. As fewer data in the literature is found, therefore the data may be helpful for manufacturing proximal femur implants.

Restoration of medial offset is important for the restoration of normal hip biomechanics. Especially in leg length inequality. Techniques such as digital templating are used for increasing the effectiveness of total hip arthroplasty. Older techniques used were the use of carpenter’s level, arithmetic formula, and a caliper.

A comparison of medial offset measured by plain x-ray and CT scan did not show much difference. Similar to our results were found in Indian, American, Chinese, Malay, and Korean populations (Verma et al., 2017; Rai et al., 2021).

Alteration in femoral or vertical offset after a total hip arthroplasty alters the gait of the patient with a lowering speed and a decreased extent of movement while walking. Increasing the VO may improve the gait but may increase the trochanteric pain. VO should be normalized according to the geometry of the acetabulum. VO in the Pakistani population was found to be greater than Indians, Americans, and other Caucasian populations (Verma et al., 2017).

FNAL has its importance in internal fixation during proximal femur fracture and total hip arthroplasties. Studies on FNAL showed an association of greater FNAL with hip fracture. Results similar to our study were found in the Chinese and Turkish populations (Hu, Liu, & Zhang, 2018; Irdesel & Ari, 2006). Nigerians, Americans, and African Americans had a smaller FNAL than our population (Katchy, Njeze, Ezeofor, & Nnamani, 2019). Biomechanically a larger FNAL protrudes the intertrochanter more. When an external force is applied the susceptibility of intertrochanteric fracture increases.

HAL in our population was variable ranging from 113.25mm to 121.64mm. The lowest was found in Urdu speaking while the highest were found in Baloch and Pashtun populations. The inter-racial differences may be due to geographical location, habits, and genetic predisposition. A reduced HAL decreases the risk of fracture, a study on the Chinese population confirmed that decreased HAL in Chinese women compared with European may be the reason for a lower incidence of hip fracture (Chin, Evans, Cornish, Cundy, & Reid, 1997).

Some authors have mentioned a greater femoral neck-shaft angle to be a risk factor of femoral neck fracture (Partanen, Jämsä, Jalovaara, & research, 2001; Szulc et al., 2006; Yamauchi et al., 2016). Association of greater FNSA with fracture was due to lower cortical thickness in the superior femoral neck region. Mid femoral cortical thickness has also been found to be a strong predictor of old age osteoporotic hip fracture. Due to bending stress in the inferior femoral neck, results in weakness and leads to fracture. In contrast, it is also suggested that a lower FNSA exerts more pressure on the intertrochanteric region than the femoral neck which can lead to intertrochanteric fracture (Johannesdottir et al., 2011). Pakistani population had an increased femoral FNSA compared with few other populations. Increased FNSA could be a reason behind the higher prevalence of femoral fracture in Pakistan (Khan, Nasim, & Hussain, 2019). Results of FNSA, similar to our study were found in Chinese, Japanese and Turkish populations (Hu, Liu, & Zhang, 2018; Irdesel & Ari, 2006; Yamauchi et al., 2016) while FNSA in Indian, Croatian, American, and European populations were smaller than our population (Gilligan, Chandraphak, & Mahakkanukrauh, 2013; Mokrovic, Komen, Gulan, & Gulan, 2021; Nayak, Baisakh, Panda, Chinara, & Vol, 2021). A study on dry femora of African-Americans and Caucasians showed similar to our results (Unnanuntana, Toogood, Hart, Cooperman, & Grant, 2010).

CHAPTER 6

CONCLUSION

Significant variations in proximal femur geometry were observed between right and left side of the same individual, between male and female gender and among different ethnic and age groups.

Significant decrease in NSA was observed with increasing age of the participants.

Our study provides data which may help the manufacturers for designing better fit implants and also help the surgeon for selection of best suited implant for different ethnic groups.

6.1 RECOMMENDATIONS

1. Further studies should also be done in multiple hospitals in order to generalize the data
2. Further studies are needed on correlation of proximal femur parameters with prevalence of fractures in different ethnic groups

6.2 STRENGTHS OF STUDY

1. This study is a pioneer in Pakistan, as previously only a few parameters of proximal femur were observed and no study was done on ethnic groups.
2. Data will guide the manufacturers and surgeons in designing and selecting best-fit implants for different ethnic groups.
3. Few parameters such as intertrochanteric length and medial offset on which fewer data were available were also measured.

6.3 LIMITATIONS

1. An unequal number of patients of different ethnic groups.
2. In few ethnic groups, the number of young participants was more than the elderly, a few parameters are age-dependent which may alter the mean values.
3. Few parameters can better be understood through CT and MRI.

CHAPTER 7

REFERENCES

Arachchi, S. M., Pinto, N. J. I. J. o. B. E., & Technology. (2020). Influence of hip geometry to intracapsular fractures in Sri Lankan women: prediction of country specific values. 33(1), 1-10.

Attum, B., & Pilson, H. (2021). Intertrochanteric Femur Fracture. In StatPearls. Treasure Island (FL): StatPearls Publishing

Boese, C. K., Dargel, J., Oppermann, J., Eysel, P., Scheyerer, M. J., Bredow, J., & Lechler, P. (2016). The femoral neck-shaft angle on plain radiographs: a systematic review. Skeletal Radiology, 45(1), 19-28. doi:10.1007/s00256-015-2236-z

Bolink, S. A. A. N., Lenguerrand, E., Brunton, L. R., Hinds, N., Wylde, V., Heyligers, I. C., . . . Grimm, B. (2019). The association of leg length and offset reconstruction after total hip arthroplasty with clinical outcomes. Clinical Biomechanics, 68, 89-95. doi:https://doi.org/10.1016/j.clinbiomech.2019.05.015

Brunner, L. C., Eshilin-Oates, L., & Kuo, T. Y. J. A. f. p. (2003). Hip fractures in adults. 67(3), 537-542.

Buly, R. L., Sosa, B. R., Poultsides, L. A., Caldwell, E., & Rozbruch, S. R. J. T. J. o. t. A. A. o. O. S. (2018). Femoral derotation osteotomy in adults for version abnormalities. 26(19), e416.

Carmona, M., Tzioupis, C., LiArno, S., Faizan, A., Argenson, J.-N., & Ollivier, M. J. T. J. o. a. (2019). Upper femur anatomy depends on age and gender: a three-dimensional computed tomography comparative bone morphometric analysis of 628 healthy patients' hips. 34(10), 2487-2493.

Chang, A., Breeland, G., & Hubbard, J. B. (2018). Anatomy, Bony Pelvis and Lower Limb, Femur.

Chang, A., Breeland, G., & Hubbard, J. B. (2020). Anatomy, Bony Pelvis and Lower Limb, Femur: StatPearls Publishing, Treasure Island (FL).

Chang, A., Breeland, G., & Hubbard, J. B. (2021). Anatomy, Bony Pelvis and Lower Limb, Femur. In StatPearls. Treasure Island (FL): StatPearls Publishing

Chang, C., Jeno, S. H., & Varacallo, M. (2021). Anatomy, Bony Pelvis and Lower Limb, Piriformis Muscle. In StatPearls. Treasure Island (FL): StatPearls Publishing

Chen, L., Liu, R., Zhao, Y., & Shi, Z. (2020). High Consumption of Soft Drinks Is Associated with an Increased Risk of Fracture: A 7-Year Follow-Up Study. Nutrients, 12(2), 530. doi:10.3390/nu12020530

Chiang, M.-H., Wang, C.-L., Fu, S.-H., Hung, C.-C., & Yang, R.-S. (2019). Does fully-threaded Headless Compression Screw provide a length-stable fixation in undisplaced femoral neck fractures? Asian Journal of Surgery, 42(1), 320-325. doi:https://doi.org/10.1016/j.asjsur.2018.05.009

Chin, K., Evans, M. C., Cornish, J., Cundy, T., & Reid, I. R. (1997). Differences in hip axis and femoral neck length in premenopausal women of Polynesian, Asian and European origin. Osteoporosis International, 7(4), 344-347. doi:10.1007/BF01623775

Chirchir, H., Ruff, C. B., Junno, J. A., & Potts, R. J. A. J. o. P. A. (2017). Low trabecular bone density in recent sedentary modern humans. 162(3), 550-560.

Cohen, D., Kogan, D., Rubin, A., Zimran, A., & Lebel, E. J. H. I. (2020). Longevity of total hip arthroplasty implants in patients with Gaucher disease. 30(2), 147-151.

De Bustamante, M. D., Alarcon, T., Menéndez-Colino, R., Ramirez-Martin, R., Otero, A., & Gonzalez-Montalvo, J. J. E. j. o. c. n. (2018). Prevalence of malnutrition in a cohort of 509 patients with acute hip fracture: the importance of a comprehensive assessment. 72(1), 77-81.

Doershuk, L. J., Saers, J. P., Shaw, C. N., Jashashvili, T., Carlson, K. J., Stock, J. T., & Ryan, T. M. J. A. j. o. p. a. (2019). Complex variation of trabecular bone structure in the proximal humerus and femur of five modern human populations. 168(1), 104-118.

Drake, R., Vogl, A. W., & Mitchell, A. W. (2009). Gray's anatomy for students E-book: Elsevier Health Sciences.

Egol, K. A., & Leucht, P. (2017). Proximal femur fractures: an evidence-based approach to evaluation and management: Springer.

Emmerson, B. R., Varacallo, M., & Inman, D. J. S. (2021). Hip Fracture Overview.

Eyüboğlu, F., Sayaca, Ç., Çalik, M., Korkem, D., Tascilar, L. N., & Kaya, D. (2020). Chapter 21 - Kinesiology of the hip. In S. Angin & I. E. Şimşek (Eds.), Comparative Kinesiology of the Human Body (pp. 375-392): Academic Press.

Fischer, C. S., Kühn, J.-P., Völzke, H., Ittermann, T., Gümbel, D., Kasch, R., . . . Lange, J. J. A. o. (2020). The neck–shaft angle: an update on reference values and associated factors. 91(1), 53-57.

Gilligan, I., Chandraphak, S., & Mahakkanukrauh, P. (2013). Femoral neck-shaft angle in humans: variation relating to climate, clothing, lifestyle, sex, age and side. Journal of anatomy, 223(2), 133-151. doi:10.1111/joa.12073.

Goyal, V., Moulton, T., & Dewald, J. P. A. (2019). A Method to Quantify Multi-Degree-of-Freedom Lower Limb Isometric Joint Torques in Children with Hemiplegia * (Vol. 2019).

Günalp, M., Gülünay, B., Polat, O., Demirkan, A., Gürler, S., Akkaş, M., & Aksu, N. M. J. L. r. m. (2014). Ionising radiation awareness among resident doctors, interns, and radiographers in a university hospital emergency department. 119(6), 440-447.

Guyen, O. J. O., Surgery, T., & Research. (2019). Hemiarthroplasty or total hip arthroplasty in recent femoral neck fractures? , 105(1), S95-S101.

Hammer, A. J. I. J. o. M. S. (2015). The paradox of Wolff's theories. *184*(1), 13-22.

Hammer, A. J. J. o. O. S. (2019). The calcar femorale: A new perspective. 27(2), 2309499019848778.

Hatem, M., Khoury, A. N., Erickson, L. R., Jones, A. L., Martin, H. D. J. A. T. J. o. A., & Surgery, R. (2021). Femoral derotation osteotomy improves hip and spine function in patients with increased or decreased femoral torsion. 37(1), 111-123.

Hayat, Z., & Varacallo, M. J. S. (2020). Surgical management of femoral neck fractures.

Hernandez-de Sosa, N., Athanasiadis, G., Malouf, J., Laiz, A., Marin, A., Herrera, S., . . . Casademont, J. J. P. o. (2016). Genetic contribution of femoral neck bone geometry to the risk of developing osteoporosis: A family-based study. 11(5), e0154833.

Hernigou, J., Schuind, F. J. B., & research, j. (2019). Tobacco and bone fractures: a review of the facts and issues that every orthopaedic surgeon should know. 8(6), 255-265.

Hsieh, C. M., Howell, S. M., Hull, M. L. J. T. I. J. o. M. R., & Surgery, C. A. (2020). Errors in femoral anteversion, femoral offset, and vertical offset following robot-assisted total hip arthroplasty. 16(4), e2104.

Hu, H., Zhan, S., & Cai, Z. (2021). Biomechanics of Hip Joints. In Hip Surgery (pp. 17-23): Springer.

Hu, Z.-S., Liu, X.-L., & Zhang, Y.-Z. (2018). Comparison of Proximal Femoral Geometry and Risk Factors between Femoral Neck Fractures and Femoral

Intertrochanteric Fractures in an Elderly Chinese Population. Chinese medical journal, 131(21), 2524-2530. doi:10.4103/0366-6999.244118

Isaac, B., Vettivel, S., Prasad, R., Jeyaseelan, L., Chandi, G. J. C. A. T. O. J. o. t. A. A. o. C. A., & Anatomists, t. B. A. o. C. (1997). Prediction of the femoral neck-shaft angle from the length of the femoral neck. 10(5), 318-323.

Jamali, A. A., Mak, W., Wang, P., Tai, L., Meehan, J. P., & Lamba, R. (2013). What is normal femoral head/neck anatomy? An analysis of radial CT reconstructions in adolescents. Clinical Orthopaedics and Related Research, 471(11), 3581-3587. doi:10.1007/s11999-013-3166-5

Johannesdottir, F., Poole, K. E. S., Reeve, J., Siggeirsdottir, K., Aspelund, T., Mogensen, B., . . . Sigurdsson, G. (2011). Distribution of cortical bone in the femoral neck and hip fracture: a prospective case-control analysis of 143 incident hip fractures; the AGES-REYKJAVIK Study. Bone, 48(6), 1268-1276. doi:10.1016/j.bone.2011.03.776

Ju, D. G., Rajaee, S. S., Mirocha, J., Lin, C. A., & Moon, C. N. (2017). Nationwide Analysis of Femoral Neck Fractures in Elderly Patients: A Receding Tide. 99(22), 1932-1940. doi:10.2106/jbjs.16.01247

Kameo, Y., Tsubota, K.-i., & Adachi, T. (2018). 3d trabecular remodeling in human proximal femur: Approach to understanding wolff’s law. In Bone Adaptation (pp. 177-185): Springer.

Kani, K. K., Porrino, J. A., Mulcahy, H., & Chew, F. S. J. S. r. (2019). Fragility fractures of the proximal femur: review and update for radiologists. 48(1), 29-45.

Katchy, A., Njeze, N., Ezeofor, S., & Nnamani, K. J. N. j. o. c. p. (2019). Geometrical analysis of the proximal femur and the clinical application in total hip replacement: a study of the Igbo population of south East Nigeria. 22(12), 1728.

Kazemi, S. M., Qoreishi, M., Keipourfard, A., Minator Sajjadi, M., & Shokraneh, S. (2016). Effects of Hip Geometry on Fracture Patterns of Proximal Femur. The archives of bone and joint surgery, 4, 248-252.

Kazley, J. M., Banerjee, S., Abousayed, M. M., & Rosenbaum, A. J. (2018). Classifications in Brief: Garden Classification of Femoral Neck Fractures. Clin Orthop Relat Res, 476(2), 441-445. doi:10.1007/s11999.0000000000000066

Keyak, J. H., Rossi, S. A., Jones, K. A., Les, C. M., & Skinner, H. B. (2001). Prediction of fracture location in the proximal femur using finite element models. Med Eng Phys, 23(9), 657-664. doi:10.1016/s1350-4533(01)00094-7

Khan, M. A. A., Nasim, O., & Hussain, Z. (2019). A Demographic Study of Fractures in Patients Presenting to A Tertiary Care Hospital in Peshawar Pakistan: A 10-Year Retrospective Analysis. 32, 98-100.

Kim, Y., Tanaka, C., Tada, H., Kanoe, H., & Shirai, T. J. B. m. d. (2015). Treatment of periprosthetic femoral fractures after femoral revision using a long stem. 16(1), 1-7.

Konda, S. R. (2018). Anatomy of the Proximal Femur. In K. A. Egol & P. Leucht (Eds.), Proximal Femur Fractures: An Evidence-Based Approach to Evaluation and Management (pp. 1-7). Cham: Springer International Publishing.

Konda, S. R. (2018). Anatomy of the Proximal Femur. In Proximal Femur Fractures (pp. 1-7): Springer.

Koval, K. J., & Zuckerman, J. D. (2000). Anatomy. In K. J. Koval & J. D. Zuckerman (Eds.), *Hip Fractures: A Practical Guide to Management* (pp. 1-8). New York, NY: Springer New York.

Kraeutler, M. J., Chadayammuri, V., Garabekyan, T., & Mei-Dan, O. (2018). Femoral Version Abnormalities Significantly Outweigh Effect of Cam Impingement on Hip Internal Rotation. 100(3), 205-210. doi:10.2106/jbjs.17.00376

Lauritzen, J. B. J. B. (1996). Hip fractures: incidence, risk factors, energy absorption, and prevention. 18(1), S65-S75.

Leslie, W. D., Lix, L. M., Morin, S. N., Johansson, H., Odén, A., McCloskey, E. V., & Kanis, J. A. (2015). Hip Axis Length Is a FRAX- and Bone Density-Independent Risk Factor for Hip Fracture in Women. The Journal of Clinical Endocrinology & Metabolism, 100(5), 2063-2070. doi:10.1210/jc.2014-4390

Lewis, D. P., Wæver, D., Thorninger, R., & Donnelly, W. J. J. T. J. o. a. (2019). Hemiarthroplasty vs total hip arthroplasty for the management of displaced neck of femur fractures: a systematic review and meta-analysis. 34(8), 1837-1843. e1832.

Lim, S.-J., Park, Y.-S. J. H., & pelvis. (2015). Plain radiography of the hip: a review of radiographic techniques and image features. 27(3), 125.

Lo, D., Talkad, A., & Sharma, S. J. S. (2020). Anatomy, Bony Pelvis and Lower Limb, Fovea Capitis Femoris.

Lu, Y., & Uppal, H. (2019). Hip Fractures: Relevant Anatomy, Classification, and Biomechanics of Fracture and Fixation. Geriatric Orthopaedic Surgery & Rehabilitation, 10, 215145931985913. doi:10.1177/2151459319859139

Mandell, J. C., Marshall, R. A., Weaver, M. J., Harris, M. B., Sodickson, A. D., & Khurana, B. J. R. (2017). Traumatic hip dislocation: what the orthopedic surgeon wants to know. 37(7), 2181-2201.

Marshall, L. M., Zmuda, J. M., Chan, B. K., Barrett-Connor, E., Cauley, J. A., Ensrud, K. E., . . . Research, M. (2008). Race and ethnic variation in proximal femur structure and BMD among older men. 23(1), 121-130.

Matthews, A. H., & Stitson, D. J. S. (2020). Osteonecrosis (Avascular Necrosis).

Medicine, H. I. J. N. E. J. o. (2019). Total hip arthroplasty or hemiarthroplasty for hip fracture. 381(23), 2199-2208.

Meeusen, R. A., Christensen, A. M., & Hefner, J. T. J. J. o. f. s. (2015). The use of femoral neck axis length to estimate sex and ancestry. 60(5), 1300-1304.

Melaku, Y. A., Gill, T. K., Appleton, S. L., Taylor, A. W., Adams, R., & Shi, Z. J. N. (2017). Prospective associations of dietary and nutrient patterns with fracture risk: a 20-year follow-up study. 9(11), 1198.

Mokawem, M., Bobak, P., & Aderinto, J. (2012). The management of pertrochanteric fractures of the hip. Orthopaedics and Trauma, 26, 112-123. doi:10.1016/j.mporth.2012.04.001

Mokrovic, H., Komen, S., Gulan, L., & Gulan, G. (2021). Radiographic analysis of the proximal femoral anatomy in the Croatian population. International Orthopaedics, 45. doi:10.1007/s00264-021-04942-5

Molino, G., Dalpozzi, A., Ciapetti, G., Lorusso, M., Novara, C., Cavallo, M., . . . Vitale-Brovarone, C. J. J. o. t. m. b. o. b. m. (2019). Osteoporosis-related variations of trabecular bone properties of proximal human humeral heads at different scale lengths. 100, 103373.

Moore, K. L., & Dalley, A. F. (2018). Clinically oriented anatomy: Wolters kluwer india Pvt Ltd.

Moore, K., Persaud, T., & Torchia, M. J. S. C. (2015). The Developing Human 10th Edition: Clinically Oriented Embryology.

Nayak, L., Baisakh, P., Panda, S. K., Chinara, P. K. J. I. J. C. R. R., & Vol. (2021). Co-relation between Hip Axis Length and Femoral Neck-Shaft Angle with Body Mass Index of Indian Population: A Radiological Study. 13(08), 115.

Nihat, A., & Meric, U. J. S. T. F. D. (2017). Radiological evaluation of the proximal femoral geometric features in the Turkish population. 24(4), 127-134.

Pacheco, L. S., Lacey Jr, J. V., Martinez, M. E., Lemus, H., Araneta, M. R. G., Sears, D. D., . . . Anderson, C. A. J. J. o. t. A. H. A. (2020). Sugar-Sweetened Beverage

Intake and Cardiovascular Disease Risk in the California Teachers Study. 9(10), e014883.

Palocaren, T. J. I. j. o. o. (2018). Femoral neck fractures in children: a review. 52, 501-506.

Partanen, J., Jämsä, T., Jalovaara, P. J. J. o. b., & research, m. (2001). Influence of the upper femur and pelvic geometry on the risk and type of hip fractures. 16(8), 1540-1546.

Pierre, M. A., Zurakowski, D., Nazarian, A., Hauser-Kara, D. A., & Snyder, B. D. J. J. o. b. (2010). Assessment of the bilateral asymmetry of human femurs based on physical, densitometric, and structural rigidity characteristics. 43(11), 2228-2236.

Pires, R. E. S., Prata, E. F., Gibram, A. V., Santos, L. E. N., Lourenço, P. R. B. d. T., & Belloti, J. C. J. A. o. b. (2012). Radiographic anatomy of the proximal femur: correlation with the occurrence of fractures. 20, 79-83.

Prasad, N., Shivashankarappa, A., Pavan, P. H., Shruthi, B., & Saheb, S. H. J. I. J. O. S. (2017). A study on segments of humerus and its clinical importance. 3(4), 752-754.

Rai, A. K., Yadav, S., Verma, V., Anand, S., Shekhar, S. J. J. o. C. O., & Trauma. (2021). Analysis of vertical and horizontal offsets in displaced femoral neck fracture in elderly treated with indigenous bicentric bipolar hip device. 13, 143-146.

Rai, A. K., Yadav, S., Verma, V., Anand, S., Shekhar, S. J. J. o. C. O., & Trauma. (2021). Analysis of vertical and horizontal offsets in displaced femoral

neck fracture in elderly treated with indigenous bicentric bipolar hip device. 13, 143-146.

Ramage, J. L., & Varacallo, M. (2021). Anatomy, Bony Pelvis and Lower Limb, Medial Thigh Muscles. In StatPearls. Treasure Island (FL): StatPearls Publishing

Romeo, N. M., Firoozabadi, R. J. C. o., & research, r. (2018). Classifications in brief: the pipkin classification of femoral head fractures. 476(5), 1114.

Ryan, T. M., & Shaw, C. N. J. P. o. t. N. A. o. S. (2015). Gracility of the modern Homo sapiens skeleton is the result of decreased biomechanical loading. 112(2), 372-377.

Sadeghi, C., Prentice, H. A., Okike, K. M., & Paxton, E. W. (2020). Treatment of Intertrochanteric Femur Fractures with Long versus Short Cephalomedullary Nails. The Permanente journal, 24, 19.229. doi:10.7812/TPP/19.229

Sadler, T. W. (2018). Langman's medical embryology: Lippincott Williams & Wilkins.

Shaikh, A., Desai, M., Kantanavar, R., & Shah, K. J. A. t. (2021). Femoral Head Fracture Without Associated Hip Dislocation. 8, 145-149.

Sheehan, S. E., Shyu, J. Y., Weaver, M. J., Sodickson, A. D., & Khurana, B. J. R. (2015). Proximal femoral fractures: what the orthopedic surgeon wants to know. 35(5), 1563-1584.

Shen, M., Wang, C., Chen, H., Rui, Y. F., & Zhao, S. (2016). An update on the Pauwels classification. J Orthop Surg Res, 11(1), 161. doi:10.1186/s13018-016-0498-3

Siwach, R. J. A. o. t. N. A. o. M. S. (2018). Anthropometric study of proximal femur geometry and its clinical application. 54(04), 203-215.

Srisaarn, T., Salang, K., Klawson, B., Vipulakorn, K., Chalayon, O., Eamsobhana, P. J. J. o. c. o., & trauma. (2019). Surgical correction of coxa vara: Evaluation of neck shaft angle, Hilgenreiner-epiphyseal angle for indication of recurrence. 10(3), 593-598.

Szulc, P., Duboeuf, F., Schott, A., Dargent-Molina, P., Meunier, P., & Delmas, P. J. O. i. (2006). Structural determinants of hip fracture in elderly women: re-analysis of the data from the EPIDOS study. 17(2), 231-236.

Toogood, P. A., Skalak, A., & Cooperman, D. R. (2008). Proximal Femoral Anatomy in the Normal Human Population. Clinical Orthopaedics and Related Research, 467(4), 876. doi:10.1007/s11999-008-0473-3

Tsikandylakis, G., Mohaddes, M., Cnudde, P., Eskelinen, A., Kärrholm, J., & Rolfson, O. J. E. o. r. (2018). Head size in primary total hip arthroplasty. 3(5), 225-231.

Umer, M., Sepah, Y. J., Khan, A., Wazir, A., Ahmed, M., & Jawad, M. U. J. J. o. o. s. (2010). Morphology of the proximal femur in a Pakistani population. 18(3), 279-281.

Verma, M., Joshi, S., Tuli, A., Raheja, S., Jain, P., Srivastava, P. J. J. o. c., & JCDR, d. r. (2017). Morphometry of proximal femur in Indian population. 11(2), AC01.

Veronese, N., & Maggi, S. (2018). Epidemiology and social costs of hip fracture. Injury, 49(8), 1458-1460. doi:https://doi.org/10.1016/j.injury.2018.04.015

Villette, C., Zhang, J., Phillips, A. J. B., & mechanobiology, m. i. (2019). Influence of femoral external shape on internal architecture and fracture risk. 1-11.

Wang, M. C., Aguirre, M., Bhudhikanok, G. S., Kendall, C. G., Kirsch, S., Marcus, R., & Bachrach, L. K. (1997). Bone mass and hip axis length in healthy Asian, black, Hispanic, and white American youths. J Bone Miner Res, 12(11), 1922-1935. doi:10.1359/jbmr.1997.12.11.1922

Weir, C. B., & Jan, A. J. S. (2019). BMI classification percentile and cut off points.

Yamauchi, K., Naofumi, M., Sumida, H., Fukuta, S., Hori, H. J. S., & Anatomy, R. (2016). Comparison of morphological features in the femur between femoral neck fractures and femoral intertrochanteric fractures. 38(7), 775-780.

Young, E. Y., Gebhart, J., Cooperman, D., & Ahn, N. U. (2013). Are the left and right proximal femurs symmetric? Clinical Orthopaedics and Related Research, 471(5), 1593-1601. doi:10.1007/s11999-012-2704-x

Zhu, Q., Shi, B., Xu, B., & Yuan, J. J. H. I. (2019). Obtuse triangle screw configuration for optimal internal fixation of femoral neck fracture: an anatomical analysis. 29(1), 72-76.

Zijlstra, W. P., De Hartog, B., Van Steenbergen, L. N., Scheurs, B. W., & Nelissen, R. G. J. A. o. (2017). Effect of femoral head size and surgical approach on risk of revision for dislocation after total hip arthroplasty: An analysis of 166,231 procedures in the Dutch Arthroplasty Register (LROI). 88(4), 395-401

(A) FRC Approval Letter

FACULTY RESEARCH COMMITTEE
BAHRIA UNIVERSITY MEDICAL & DENTAL COLLEGE

Date: 4th December, 2020

To,
Dr. Saneed Khaliq
Department of Anatomy
BUMDC-Karachi

Subject: **Approval of Revised Title of MPhil Synopsis**

Dear Student:

The revised title of Synopsis of the MPhil student, **Dr. Saneed Khaliq, Department of Anatomy,** has been approved in 20th FRC meeting, on recommendation of Principal Supervisor, as minor change without changing the main theme. The approved revised title are as follow:

Revised Title: **"Evaluation of Proximal Femur Geometry on Plain Radiographs among Different Ethnics Groups."**

FOR:

Old Title: "Evaluation of Femoral Neck Shaft Angle on Plain Radiographs among Different Age Groups."

It is further requested to submit three copies of synopsis with revised tittle to FRC office within one week for further processing and record.

Regards,

Dr. Mehreen Lateef,
Associate Professor,
CO- CHAIRPERSON FRC-BUMDC

Cc:
DG-BUMDC,
Principal Supervisor,
PGP-TM Secretariat,
Principal Medical,
Co-chairperson FRC,

Faculty Research Committee, Bahria University Medical College
Sailor's Street, Adjacent PNS-SHIFA DHA
Webmail: rrc-bumdc@bahria.edu.pk

(B) ERC Approval Letter

BAHRIA UNIVERSITY MEDICAL AND DENTAL COLLEGE

Defence phase II, Sailor Street, adjacent to PNS Shifa, Karachi. Tel: 021-35319491-9

ETHICAL REVIEW COMMITTEE

LETTER OF APPROVAL

Date: 19-January-21

Reference:
FRC/BUMDC - 13/2020-Ana-114

PATRON
Prof. Ambreen Usmani
Principal & Dean
Health Sciences(BU)

CHAIRPERSON
Dr. Quratulain Javaid

SECRETARY
Dr. Ambreen Surti

MEMBERS
Prof M Alamgir
Prof Anis Jafarey
Ms Nighat Huda
Surg Cdre Amir Ejaz
Prof Reza H Syed
Ms Shabina Arif
Mr M Amir Sultan
Surg Lt Cdr Farah
Surg Lt Cdr Sadia

Dr. Saneed Khaliq
M-Phil Student
Department of Anatomy
BUMDC

Subject: Institutional Approval of research study

Title of Study: "Evaluation of Proximal Femur Geometry on Plain Radiographs among Different Ethnic Groups"

Principal Investigator: Dr. Saneed Khaliq

Reference No: ERC 66 /2021

Dear Dr. Saneed Khaliq,

Thank you for submitting the above mentioned study proposal. ERC Bahria University Medical and Dental College has reviewed this project in the meeting held on 18-January-2021 and gives approval. Kindly notify us when the research is complete.

Regards,

19/1/21

DR. QURATULAIN JAVAID
Chairperson, ERC
BUMDC

Cc:
DG-BUMDC
Principal BUMDC
Chairperson ERC

(C) Consent Form English version

WRITTEN INFORMED CONSENT FORM OF PARTICIPANT

I am giving my consent to participate voluntarily and at my own will in the research project that aims for measurement of proximal femur and prevention of hip fracture. The project will evaluate parameters of variations of femoral neck shaft angle in the subjects with hip pain by use of X-ray hip bone. In which there is a risk of 0.7mv radiation.

I have been explained in detail the nature and significance of participating in the project and I understand the provided explanation.

I have been told that findings of my disease and my data will be kept strictly confidential and will be used only for the benefit of community, publications and paper presentations.

I have been explained that laboratory investigations will be conducted to evaluate my health status and to diagnose and monitor my disease process. For this purpose, I fully agree to give film of X-ray hip to the researcher.

I also agree to give all relevant information needed, in full and to the best of my knowledge to the researcher. It is clarified to me that no incentive, financial assistance or reimbursement will be provided to me for participating in the study whereas I do have the right to withdraw from the study at any time.

I am advised to contact Dr. Saneed Khaliq on mobile number: 0334-2486886

or visit PNS Shifa hospital in case of query/ emergency related to my disease.

Name of Participant: ____________________S/o, D/o, W/o_________________

Signature of Participant: ____

Name of Researcher: ____

Signature of Researcher: __________________________________

Date: _________________

Urdu version

مریض کے لئے رضامندی فارم

میں رضاکارانہ طور پر اور اپنی مرضی سے اس تحقیقی منصوبے میں حصہ لینے کے لئے اپنی رضامندی دے رہا /رہی ہوں جس کا مقصد قریبی فیمر کی پیمائش اور کولہے کے فریکچر کی روک تھام کرنا ہے۔ پروجیکٹ ایکسرے ہپ ہڈی کے استعمال سے کولہوں میں درد کے ساتھ مضامین میں فیمورل گردن شافٹ زاویہ کی مختلف حالتوں کے پیرامیٹرز کا اندازہ کرے گا. جس میں مریض کو 0.7 ایم وی تابکاری کی کا خطرہ ہوتا ہے

مجھے منصوبے میں حصہ لینے کی نوعیت اور اہمیت کے ساتھ تفصیل سے بتایا گیا ہے اور میں فراہم کردہ وضاحت کو سمجھتا ہوں۔

مجھے بتایا گیا ہے کہ میرے مرض اور میرے ڈیٹا کی کھوج کو سختی سے خفیہ رکھا جائے گا اور یہ صرف معاشرے ، اشاعتوں اور کاغذی پریزنٹیشن کے لئے استعمال ہوگا۔

مجھے بتایا گیا ہے کہ میری صحت کی صورتحال کا اندازہ کرنے اور میری بیماری کے عمل کی تشخیص اور نگرانی کے لئے لیبارٹری کی تحقیقات کی جائیں گی۔ اس مقصد کے لئے میں محقق کو ایکس رے ہپ کی فلم دینے پر پوری طرح اتفاق کرتا ہوں۔

میں پوری طرح سے اور اپنی جانکاری کی بہترین تحقیق محقق کو دیتا ہوں۔ یہ بات مجھ پر واضح کی گئی ہے کہ مطالعے میں حصہ لینے کے لئے مجھے کوئی مراعات ، مالی مدد یا معاوضہ فراہم نہیں کیا جائے گا جبکہ مجھے کسی بھی وقت مطالعے سے دستبردار ہونے کا حق حاصل ہے۔

مجھے مشورہ دیا گیا ہے کہ موبائل نمبر: 0334-2486886 پر ڈاکٹر سنید خالق سے رابطہ کروں

یا میری بیماری سے متعلق سوال / ایمرجنسی کی صورت میں پی این ایس شیفا اسپتال سے رابطہ کرویں۔

شریک کا نام: ______________________ ولد/ بنت/ زوجہ ______________________

شریک کے دستخط: ____

محقق کا نام: ____

محقق کے دستخط: ____

(D) Subject evaluation form

تاریخ: ______________________________

SUBJECT EVALUATION FORM

Name:	S/o, d/o, w/o	Patient Id:	Date:
Gender:	Age:	Height:	Weight:
BMI:	Marital Status:	Ethnicity:	Comorbidities:
Ph No:	Occupation:	Smoking:	Pan/Gutka/Betel nuts:

Has hip Pain: Yes No

If Yes:

Duration of hip Pain: ______________________________

Frequency of hip Pain: ______________________________

When do you experience hip pain? ______________________________

Has the pain disrupted daily activities: Yes No

Does the pain disturb your sleep? Yes No

Do you need to rest frequently due to hip pain? Yes No

Do you find it difficult to get up from a chair? Yes No

Do you use hip care equipment? Yes No

Are you taking any medication for the hip pain? Yes No

Do you exercise? Yes No

How often do you exercise? Daily | 2-3 times a Week | Weekly | Monthly

Take soft drinks Daily | 2-3 times a Week | Weekly | Monthly

PROXIMAL FEMUR MEASUREMENTS

1. **Femoral NSA (neck shaft angle) in degrees:**
   Right_______________Left_______________

2. **Femoral head diameter: ---------------mm**
   Right_______________Left_______________

3. **Femoral neck diameter: ----------------mm**
   Right_______________Left_______________

4. **Femoral neck length: --------------------mm**
   Right_______________Left_______________

5. **Intertrochanteric length: ---------------mm**
   Right_______________Left_______________

6. **Medial offset: ------------------------------mm**
   Right_______________Left_______________

7. **Vertical offset: ---------------------------mm**
   Right_______________Left_______________

8. **Femoral axis length: ---------------------mm**
   Right_______________Left_______________

9. **Hip axis length: -------------------------mm**
   Right_______________Left_______________

(E) Plagiarism report

ORIGINALITY REPORT

12%	7%	8%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Higher Education Commission Pakistan Student Paper	3%
2	repository-tnmgrmu.ac.in Internet Source	1%
3	Shveta Swami, Tarsem Kumar, Deepak Sharma. "Correlation of handedness with hand anthropometric measurements in Haryanvi Brahmins", Journal of the Anatomical Society of India, 2015 Publication	<1%
4	"European Surgical Orthopaedics and Traumatology", Springer Science and Business Media LLC, 2014 Publication	<1%
5	Filiz Eyüboğlu, Çetin Sayaca, Mahmut Çalik, Duygu Korkem, Lacin Naz Tascilar, Defne Kaya. "Kinesiology of the hip", Elsevier BV, 2020 Publication	<1%

journals.lww.com