MORPHOMETRIC ANALYSIS OF

UPPER END OF FEMUR

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CERTIFICATE

This is to certify that the dissertation entitled "**MORPHOMETRIC ANALYSISOF UPPER END OF FEMUR**" is a bonafide work done by **Dr.S.P.Rathija Sreekumar**, **Sree Mookambika Institute of Medical Sciences, Kulasekharam** in partial fulfilment of the University rules and regulations for the award of **MD** in **Anatomy** under our guidance and supervision during the academic year 2013- 2016.

Dr.P.C.Kunjumon.MS

(Guide)

Professor & Head of the Department
Department of Anatomy
Sree Mookambika Institute of
Medical Sciences,
Kulasekharam.

Dr.G.V.Hebbal.M.Sc,PhD (Med.fac)

(Co-guide)

Professor
Department of Anatomy
Sree Mookambika Institute of
Medical Sciences,
Kulasekharam.

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Dr.Rema.V.Nair.MD(OB&G), DGO

The Director
Sree Mookambika Institute of Medical Sciences,
Kulasekharam [K.anyaKumari District]
Tamil Nadu- 629 161.

Dr.P.C.Kunjumon.MS

(Guide)
Professor & Head of the Department
Department of Anatomy
Sree Mookambika Institute of Medical Sciences,
Kulasekharam. [KanyaKumar District]
Tamil Nadu- 629 161.

DECLARATION

I Solemnly declare that the dissertation **'MORPHOMETRIC STUDY OF UPPER END OF FEMUR'** was prepared by me at Sree Mookambika Institute of Medical Sciences, Kulasekharam under the guidance and supervision of **Dr.P.C.Kunjumon**. M.S, Professor & HOD, Department of Anatomy, Sree Mookambika Institute of Medical Sciences, Kulasekharam. This dissertation is submitted to **The Tamilnadu Dr.M.G.R Medical University, Chennai** in partial fulfilment of the University regulations for the award of the degree of **M.D (Anatomy).**

Place: Kulasekharam.

Date: **DR. S.P.RATHIJA SREEKUMAR**

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CONTENTS

SL.NO.	INDEX	PAGE NO.
1.	INTRODUCTION	1-4
2.	AIMS AND OBJECTIVES	5
3.	REVIEW OF LITERATURE	6-48
4.	MATERIALS AND METHODS	49-58
5.	RESULTS	59-72
6.	DISCUSSION	73-78
7.	SUMMARY AND CONCLUSION	79-80
8.	BIBLIOGRAPHY	
9.	ANNEXURES	

LIST OF ABBREVATIONS

CDA - Collo diaphyseal angle.

NSA - Neck Shaft angle.

HTD - Head transverse diameter.

NTD - Neck transverse diameter.

HVD - Head vertical diameter.

NVD - Neck vertical diameter.

PB - Proximal breadth.

FA - Femoral anteversion.

BMI - Body mass index.

BMD - Bone mineral density.

FNL – Femoral neck length.

FNW - Femoral neck width.

FHD - Femoral head diameter.

FAL – Femoral axis length.

DHS - Dynamic hip screw.

PFN - Proximal femoral nails.

SD - Standard deviation.

INTRODUCTION

Femur is the thigh bone which is the longest and strongest bone of the body. It provides skeletal support for the thigh. It consists of a proximal end, a shaft and a distal end. The proximal end of femur consists of a head, a neck and on the upper part of the shaft there are two large projections known as greater trochanter and lesser trochanter.

Femur has a spherical head that articulates with the acetabulum of the pelvic bone. On its medial surface, it has a non- articular pit called fovea which gives attachment to the round ligament of the head of the femur.

Femoral neck is a cylindrical strut of bone which connects the head to the shaft of the femur. Approximately at an angle of 125^0 the neck projects superomedially from the shaft and also it projects slightly forwards. The greater and lesser trochanters provides attachments to the muscles that move the hip joint.[1]

Approximately the neck of the femur is 5cms long and connects the head and the shaft at an angle. This is known as the angle of inclination or the neck-shaft angle or collo diaphyseal angle (CDA) or cervico diaphyseal angle of the femur. In most of the cases, the collo diaphyseal angle on the right side is lesser than that of the left side and there was no significant differences between the two sexes.[2]

Fractures involving the neck and trochanter of the proximal end of the femur are very common. Internal fixation with implants for these fractures are important for rehabilitation and early mobilization of the patients. Depending upon the dimensions of the upper end of the femur, the implants are designed. Currently most of the orthopaedic surgeons need notifications in the dimensions of the implants that suits the Indian standards.[3]

To measure the dimensions of the femur, various methods are used by researchers. The femur dimensions on cadaveric bones are measured mechanically, but in patients, various methods such as ultrasound, roentgenography, computerised tomography (CT) and magnetic resonance imaging (MRI) are used. Number of studies in femur dimensions varies according to the methods adopted and according to the populations.[4]

On the basis of measurements performed in Causasians, the implants are used for the treatment of proximal femur fractures including the 135^0 cervico diaphyseal angle. At birth the cervico diaphyseal angle measures about an average of 160^0 and is greater but along with the skeletal growth the angle decreases and in adults the cervico diaphyseal angle measures on an average of 135^0. So for the manufacture of implants used in the orthopaedic surgery, the reference value of about 135^0 is used.[5]

For pre-operative assessment of the size of the implants, combined use of computerised tomography and radiography is recommended, especially in the cemented arthroplasty where it is essential for an optimal biological fixation.[6] Anthropometry gives various techniques and scientific methods for taking number of measurements in the different races and geographical regions.[7]

The individuals in the central Indian population have medium femora when compared to the other available data.[8] In India, very few studies have been done on morphometry of the femur and these studies reveal that in Indian population the results of western studies are not applicable because the measurements of the femora differ in both populations.[9]

Proximal femur morphology is a necessary parameter for designing and implant development in the total hip replacement. Use of inappropriately designed implants and their size affects the outcome of the surgery with some complications such as micromotion, loosening and stress shielding. Implants are mostly manufactured and designed in North America and European region which are designed, based on morphology of their population.[10]

Femoral neck fractures are mostly intracapsular and as a result of the fracture, the cervical vessels which are formed from subsynovial intra articular ring are disrupted. Therefore head of the femur may be necrosed in such cases and it is necessary to carry out a total hip replacement or hemiarthroplasty. Intertrochanteric fracture is another typical fracture around the hip joint. In this case femoral neck is not involved and usually fracture line begins from greater trochanter to the lesser trochanter.[1]

Femoral neck blood supply is preserved in intertrochanteric fractures. These types of fractures are usually corrected by the surgeries using femoral plate and a pin that obtains alignment to the central portion of the neck of the femur. Early mobilization allows the fractures to heal well.[1]The collo-diaphyseal angle gives greater mobility at the hip joint. Any difference identified from a normal neck shaft angle (NSA) of the femur reflects the anatomical variation or acquired origin or disease. Decrease in the neck shaft angle of the femur is termed as coxavara. In this case, the femoral head position tends to seat very deep in the acetabulum and the hip remains very stable. Increase in the neck shaft angle is termed as coxavalga. In this case, the hip tends to have very less contact with the dorsal acetabulum and it may result in the subluxation or luxation.[2] Reduction of bone mineral density is a characteristic feature of a disease called osteoporosis. Proximal femur is the most susceptible site of osteoporosis. Mechanical properties of the bone is reduced in osteoporosis.[11]An important indicator of femoral fracture is low bone mineral density.[12] Bone mineral density cannot evaluate the fracture risk. There are also certain patients who present with normal bone mineral density but with high fracture risk.[13]

This study will enlighten the implant designers to take a step on altering the designs of the implants that suits our Indian needs.

AIMS AND OBJECTIVES

1. To describe

   The angle between neck and shaft (NSA) on both sides.

   Head vertical diameter (HVD) on both sides.

   Neck vertical diameter (NVD) on both sides.

   Head transverse diameter (HTD) on both sides.

   Neck transverse diameter (NTD) on both sides.

   Proximal breadth (PB) on both sides.

2. To find out whether there is any significant differences between right and left femur.

REVIEW OF LITERATURE

Review of literature is described under following headings:

1.Anatomy of the Femur

2.Blood supply of a long bone

3.Embryogenesis of a long bone

4.Measurements of proximal femur

5.Different methods used to measure the femoral geometry

6.Femoral fractures

7. Implants used

1. ANATOMY OF FEMUR:

The femur is a long bone which consists of an upper end, a shaft and a lower end. The proximal end of the femur is distinguished from the distal end by the presence of a rounded head which joins with the shaft by an elongated neck. The head of the femur is directed medially and it articulates with the acetabulum of the hip bone.

The anterior aspect and the posterior aspect of the femur can be identified by examining the shaft of the bone. The anterior aspect of the shaft is smooth and convex forwards, whereas its posterior aspect has a prominent vertical ridge called the linea aspera.

The upper end:

The femur consists of two projections in its upper end known as greater trochanter and lesser trochanter. Apart from being directed medially the head is also directed upwards and a little forwards. Femoral head is much more rounded when compared to the head of the humerus and it is slightly more than half a sphere. A pit or a fovea can be seen near the centre of the femoral head.

The neck of the femur connects the head to the shaft at an angle of 125^0. The neck is about 5cms long.

The greater trochanter is formed as a large quadrangular projection on the lateral side of the proximal end of femur. Its superior and posterior part projects upwards beyond the level of the neck and thus have a medial surface. On this medial surface there is a depressed area called the trochanteric fossa.

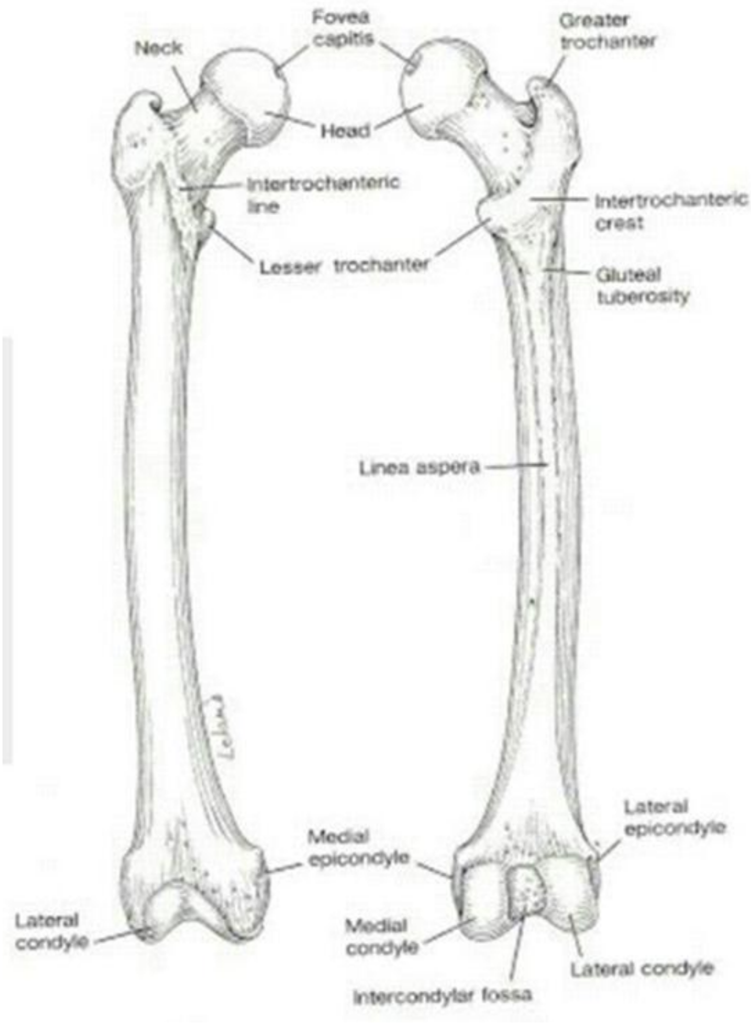

Fig:1, Anterior and Posterior aspects of Femur.

The lesser trochanter is in the form of a conical projection which arises from the shaft, where the lower border of the neck meets the shaft. It is directed medially and backwards. Posteriorly, the greater and the lesser trochanters are joined together by a prominent ridge called the intertrochanteric crest. This crest bears a rounded elevation a little above its middle called the quadrate tubercle. On the anterior aspect, the junction of the neck and the shaft of the femur is marked by a very less prominent intertrochanteric line. Superiorly, this line reaches the anterior and upper part of the greater trochanter and inferiorly it lies a little infront of the lesser trochanter. From the lesser trochanter, the intertrochanteric line is continuous with the spiral line that runs downwards and backwards crossing the medial aspect of the shaft to reach the posterior aspect.

The Shaft:

The shaft is triangular in cross section having three surfaces (medial, lateral and anterior) and three borders (medial, lateral and posterior). The medial and lateral borders are rounded. The posterior border corresponds to the linea aspera. Here the medial and the lateral surfaces of the bone also faces backwards. The linea aspera has medial and a lateral lips. When traced upwards the medial lip becomes continuous with the spiral line and the lateral lip becomes continuous with the broad rough area called as the gluteal tuberosity. Superiorly, the gluteal tuberosity reaches the greater trochanter. On the posterior aspect, upper one third of the shaft has an area between the gluteal tuberosity and the spiral line which constitutes the posterior surface. The linea aspera diverges in the lower one third of the shaft and becomes continuous with the medial and lateral supracondylar lines. An additional triangular surface can be noted in between the two supracondylar lines known as the popliteal surface.

The lower end:

It consists of two large medial and lateral condyles. Anteriorly, the two condyles are joined and they lie in the same plane as that of the distal end of the shaft. On the posterior aspect, the medial and the lateral condyles extend beyond the plane of the shaft and here the intercondylar notch or fossa separates the condyles from each other. The side view of the lower end of the bone shows an arc with downward convexity. The medial condyle is curved a little having a medial convexity. In contrast, the lateral condyle is straight and is directed backwards and slightly laterally. An articular area can be seen in the anterior aspect of the condyles for the patella (patellar surface). The two condyles articulate with the tibia below and form the knee joint. On the lateral aspect, the lateral condyle of the femur is more or less flat and slightly behind the middle there is a prominence called lateral epicondyle. The medial aspect of the medial condyle is convex and the most prominent part on it is called the medial epicondyle. There is a small prominence at the uppermost part of the medial condyle called adductor tubercle which can be seen above and behind the medial epicondyle.[14]

2. BLOOD SUPPLY OF A LONG BONE:

Three sets of arteries are received by a long bone.

1. A nutrient artery (a diaphyseal nutrient artery) enters the marrow cavity of shaft through the nutrient foramen. In some cases more than one nutrient arteries can be seen. The foramen for the opening of nutrient artery is known as nutrient foramen. The nutrient foramen leads into a canal that goes obliquely through the shaft. The artery gives off ascending and descending branches within the marrow cavity.
2. On either side of the bone several arteries enters inside such as epiphyseal arteries and metaphyseal arteries. This epiphyseal and metaphyseal arteries supplies greater volume of blood. However, the nutrient artery is considered as the main artery of supply to bone.
3. Through minute foramina of the bone several small arteries enter the bone.

A rich sinusoidal plexus is formed in bone marrow by the branches of all these arteries. Several branches from the sinusoidal plexus enter the haversian canals. Through the canals of Volkmann, the periosteal arteries reaches the haversian canals.

In the blood supply of bone, the periosteal vessels also play an important role and towards the marrow cavity a considerable amount of blood flows inwards from the periosteum.

A large central venous sinus can be seen in the marrow cavity. The veins accompany the arteries and numerous veins drains in this sinus. Apart from bone tissue the blood vessels also supplies the periosteum, bone marrow, articular cartilages and the epiphyseal plate. Metaphyseal arteries supply the epiphyseal plate on the metaphyseal side and epiphyseal arteries supply the epiphyseal side. Lymphatic vessels are not present in bone substance but it can be seen in the periosteum. Blood vessels accompany the nerve fibres into Haversian canal and into the marrow cavity.[15]

3. EMBRYOGENESIS OF A LONG BONE:

Formation, development and growth of a long bone is described below:

Formation of a long bone:

Bone is of mesodermal origin. Ossification is the process of bone formation. Formation of a cartilaginous model preceeds the bone formation in most parts of the embryo which is gradually replaced by bone. This type of bone formation is known as endochondral ossification. In case of vault of skull, the clavicle and the mandible, the bone formation is not preceeded by the formation of cartilaginous model. The bone is laid down directly in a fibrous membrane, instead of cartilaginous model. It is called as intramembranous ossification and the bones thus formed are called as membrane bones.

Endochondral ossification:

The following steps are essential in the formation of bone, by endochondral ossification:

1. A mesenchymal condensation is formed by closely packed mesenchymal cells at the site of bone formation.
2. Hyaline cartilage is laid down by the chondroblasts (some mesenchymal cells become chondroblasts). A membrane formed on the surface of the cartilage by the mesenchymal cells is called the

perichondrium. This membrane contains osteogenic cells and is vascular.

3. At first the cells of the cartilage is small and are arranged irregularly. However the cells enlarge considerably in the area of formation of bone.
4. Between the enlarged cartilage cells, the intercellular substance become calcified under the influence of the enzyme alkaline phosphatase secreted by the cartilage cells. The nutrition to the cells is thus cut off and they die, leaving behind primary areolae (empty space).
5. Now the calcified cartilagenous matrix is invaded by the blood vessels of the perichondrium and the osteogenic cells accompany them. This mass of cells and vessels is known as periosteal bud. It forms the walls of primary areolae by eating much of the calcified matrix and create large cavities called secondary areolae.
6. A thin layer of calcified matrix forms the walls of the secondary areolae that have not been dissolved. The osteoblast (osteogenic cells become osteoblast) arrange themselves along the surface of the plates or bars of calcified cartilaginous matrix.
7. A layer of ossein fibrils is laid down by these osteoblasts and this layer is embedded in a gelatinous intercellular matrix. It is known as osteoid. The osteoid gets calcified to form lamellus of bone.

8. Over the first lamellus, another layer of osteoid is laid down by the osteoblasts. Now two lamellae of bone are formed. Between the lamellae, some osteoblasts get caught and form osteocytes. Bony trabeculae are formed as more lamellae are laid down.

The calcified matrix of cartilage supports the developing trabeculae and is not converted in to bone itself.

At this stage a central area can be seen in the ossifying cartilage, where the bone is formed. Away from this area, the followings can be seen:

a. Cartilage cells.
b. In an uncalcified matrix, a zone of hypertrophied cartilage cells
c. Normal cartilage with mitotic activity.

Development of a long bone:

A mesenchymal condensation is seen in the limb bud in the region where the bone is to be formed. The mesenchymal condensation is converted into a cartilaginous model. This model closely resembles the bone to be formed. It is covered by a superficial fibrous layer and a deeper layer that has osteogenic cells

Endochondral ossification starts in a small area of the shaft. This area is called the primary ossification. Gradually, bone formation extends from the primary centre towards the end of the shaft. This accompanied by enlargement of the cartilaginous model.

Soon after the appearance of the primary centre and onset of endochondral ossification in it, the perichondrium (which may now be called periosteum) becomes active. The osteogenic cells in its deeper layer lay down bone on the surface of the cartilaginous model by intramembranous ossification. This periosteal bone completely surrounds the cartilaginous shaft and is therefore, called the periosteal collar. It is first formed only around the region of the primary centre but rapidly extends towards the ends of the cartilaginous model. The periosteal collar acts as a splint and gives strength to the cartilaginous model, at the site where it is weakened by the formation of secondary areolae. The most of the bone shaft is derived from this periosteal collar and is, therefore, intramembranous in origin.

Growth of a long bone:

A growing bone increase both in length and in thickness. The periosteum lays down a layer of bone around the shaft of the cartilaginous model. This periosteal collar gradually extends over the whole length of the diaphysis. As more layers of bone are laid down over it, the periosteal bone become thicker and thicker. However, it is neither necessary nor desirable for it to become too thick. Hence, osteoclast come to line the internal surface of the shaft. And remove bone from this aspect. As bone is laid down outside the shaft, it is removed from inside. The shaft thus grows in diameter, and at the same time its wall does not become too thick. The osteoclasts also remove the trabeculae lying in the centre of the bone that were formed by endochondral ossification. In this way a marrow cavity is formed.

As the shaft increases in diameter, there is a corresponding increase in the size of the marrow cavity. This cavity also extends towards the ends of the diaphysis but does not reach the epiphyseal plate. Gradually, most of the bone formed from the primary centre (endochondral origin) is removed, except near the ends, so that the wall of the shaft is made up purely of periosteal bone formed by the process of intramembranous ossification.

a) Zone of resting cartilage:

The cells are small and irregularly arranged.

b) Zone of proliferating cartilage:

The cells are larger and are undergoing repeated mitosis. As they multiply, they come to be arranged in parallel columns, separated by bars of intercellular matrix.

c) Zone of calcification:

The cells become still larger and the matrix becomes calcified.

Next to the zone of calcification, there is a zone where casrtilage cells are dead and the calcified matrix is being replaced by bone. Growth in length of the bone take place by continuous transformation of the epiphyseal cartilage to bone in this zone. At the same time, the thickness of the epiphyseal cartilage is maintained by active multiplication of cells in the zone of proliferation. When the bone has attained its full length, cells in the epiphyseal cartilage stop proliferating. The process of ossification, however, continues to extend into it until the whole of the epiphyseal plate is converted into bone. The bone of the diaphysis and epiphysis then becomes continuous. This is called fusion of epiphysis.[16]

4. MEASUREMENTS OF PROXIMAL FEMUR:

In 1889, **Humphry.G** et al conducted a study on the angle of the neck with shaft of the femur at different periods of life and under different circumstances and said that the collo diaphyseal angle (CDA) was very stable from mid adolescence.[17]

In 1914, **Parsons.F.G** et al, documented that in females the femoral anteversion (FA) was greater on right side when compared to left side.[18]

In 1941, **Pick.J.W** et al, studied the measurements on the human femur: length, diameter and angle by radiographic assessment, measurements taken from 100 males and 100 females and documented that females having larger neck shaft angle when compared to males.[19]

In 1945, **Elftman.H** et al, did a study on Torsion of lower extremity and the average value of adult femoral anteversion (FA) and found range between 7^0– 16^0 in multiple skeletal surveys.[20]

In 1958, **Breathnach** et al, the author of classic Anatomy text book quoted the angle of inclination as 120 degrees that may vary from 110^0 to 140^0.[21]

In 1968, **Kate.B.R** et al, had described the average neck shaft angle as 123.5^0 by observing 1000 femora and he found that the Formosans have lowest neck shaft angle of an average of about 125.6^0 and Andamanians have the highest angle of an average of about 134^0.[22]

In 1970, **Chhibber** and **Singh** found that the left limb is dominant. They stated that whether a person is right handed or left handed, for weight bearing, most of the people use their left lower limb.[23]

In 1980, **Hoaglund** et al, did a comparative study on the anatomy of upper end of femur between normal Causasians and Hong Kong people. He identified the differences in the geometry of head, neck and proximal femoral shaft and found the average collo diaphyseal angle (CDA) of Causasians as 135^0 and the anteversion angle as 8^0.[24]

In 1982, **Reikeras.O** et al, studied femoral neck angle measured in 48 pairs of normal femora from cadavers of Norwegians. He found that the cervico diaphyseal angle of males was about $128.3^0 \pm 7.9^0$ and in the female it was about $127^0 \pm 7.2^0$ and specified that no significant sex differences were found.[25]

In 1985, **Staheli.L.T** et al, detected the lower extremity rotational problems in children and the normal values to guide management. He stated that the femoral neck anteversion gradually increases with gestational age and reported that at the third month it was about 0^0, after four months it was noted to be $+12^0$ and at the time of birth the femoral neck anteversion was $+24.4^0$. By detorsion in childhood it would change till it reaches the average angle of $+12^0$.[26]

In 1993, **Issac.B** et al, studied neck shaft angle of femur and found that the average collo diaphyseal angle (CDA) as 127.5^0.[27]

In 1993, **Trikaus.E** et al, detected femoral neck shaft angles (NSA) of Qafzeh-skuhl early modern humans and activity levels among immature near Eastern middle Paleolithic hominids and said that, from mid adolescence through most of adulthood, the angle of inclination (AI) was very stable.[28]

In 1996, **Ranganathan.T.S**, author of Anatomy text book quoted that the average cervico diaphyseal angle was about 125^0 in adults and 140^0 in foetuses.[29]

In 1996, **Karlsson** et al, described the morphology of upper end of femur and explained the differences in the morphology of the upper end of femur in population studies and races.[30]

In 1997, **Strecker.W** et al studied the length and torsion of the lower limb and concluded that when compared to right femora, the left femora showed higher values but they were not significantly greater.[31]

In 1998, **Anderson.J.Y** et al, studied the pattern of bilateral and inter populational variations in human femoral neck shaft angles and stated that the climate, race and geography also has a role on patterning in femoral collo diaphyseal angle.[32]

In 1998, **Dithie.R** et al, presented the morphometric study by using femora. The study showed significantly higher values of femoral neck length and width for both men and women. There was an envoluntary change in the morphometric pattern of Scottish population which was compared to 1920 specimens of skeleton from 90's.[33]

In 1999, **Gnudi.S** et al prepared a geometry of proximal end of femur in the prediction of hip fracture in osteoporotic women and showed the value of collo diaphyseal angle in radiographic studies, data's were collected from 329 females and reported that the neck shaft angle was about 122.6^0 among the Italian populations.[34]

In 2000, **Leelavathy.N** et al, did a study on sexing of the femora and published that there is variation in the maximum length of the femur with a maximum value of 512mm and minimum of 371mm, when this range is compared to the known sex, they identified the sex of 29 femora from 40 sample and documented that out of 29 identified femora, 18 belongs to males and 11 to females. They also observed that male femur is longer than female femora and also observed that in males right femora is shorter than left and vice versa in females.[35]

In 2002, **Ziylan.T** et al, identified the geometry of femur from Anatolian population from two different ages according to normal parametric measurements. The study obtains eleven femoral parameters including neck shaft angle. 36 right and 36 left human adult femora were used. For this study an osteometric board, a sliding calliper, goniometer and a tapeline were used. The study was also compared with the previous studies of human femora from Hoyuk area. This study showed that, between the right and left femora, there was no significant differences but the head vertical diameter reveals some difference. The maximum length was determined from the femoral head to the medial condyle, trochanter length was measured from the tip of the greater trochanter to the lateral condyle of the femur, the neck shaft angle was measured from the angle between the long axis of neck and shaft, the proximal breadth was between the femoral head and the greater trochanter, vertical diameter of the head measures the head of femurs maximum vertical diameter, the maximum antero-posterior diameter of femoral head was measured as the head transverse diameter.

Transverse diameter of the neck was the minimum diameter of the femoral neck at antero-posterior diameter. Antero-posterior diameter of mid shaft was the minimum antero-posterior diameter of the femoral shaft at the middle. At the midpoint of shaft, the minimum transverse diameter was considered as a mid- shaft transverse diameter. The result concluded that the geometry of femoral measurements showed the differences in the values obtained from various populations and also varies depending on the age.[36]

In 2002, **Cauhan** et al, established Anatomical parameters of North Hip joints, a cadaveric study concluded that among the various populations in India, the variations in the parameters of acetabulum and the proximal femur were insignificant but there was a significant variation between the data of two different countries.[37]

In 2003, **Siwach.R.C** et al, used 75 pairs of femora and observed that the average collo diaphyseal angle as 123.5^0, maximum effective neck length was about 3.72cms, minimum neck length was about 2.26cms, anteroposterior neck width was about 2.49cms and superoinferior neck width was about 3.18cms and found a geometrical variation between the Indian femora and the Western implants. Use of such implants leads to mal union and avascular necrosis.[38]

In 2004, **Pulkinen** et al, did a study on combination of bone mineral density and upper femur geometry to improve the prediction of hip fracture by using radiography and concluded that the collo diaphyseal angle was about 128.3^0 that was analysed in 40 females.[39]

In 2004, **Calis.H.T** et al, evaluated the morphology of upper end of femur in adult bones and explained the difference in morphology of the upper end of femur in population studies and races.[40]

In 2005, **Nissen** et al, studied the geometry of the proximal femur in relation to age and sex, a cross sectional study in healthy adult Danes by radiography. He collected data from 249 adults and documented that the average collo diaphyseal angle of males was about 131 ± 5^0 and that of the females was about 125 ± 5^0.[41]

In 2006, **Irdesel** and **Ari.I,** did a study on proximal femoral morphometry on radiography of Turkish women. The study aimed to measure the parameters in femur and the body mass index. Both the body mass index (BMI) and femoral upper end morphometry were very important determinants of fracture. Generally in elderly people, the hip fractures have high mortality and morbidity rates. The study was conducted in 190 Turkish women. The body mass index and the anthropometric measurements were noted. The proximal morphometry were measured on the radiographs. The study excluded the women with terminal diseases, malignancy, metabolic bone diseases, cox arthrosis or renal failure.

Hip was internally rotated about $15\text{-}30^0$ in supine position and at a distance of 100cm a film-focused and on the symphysis pubis, the beam is centered. This was the procedure used to measure the morphometry of femur on radiography in this study. They concluded that the average Q angle was 131.5^0, femoral neck length was 10.8cm, cross section of the head of femur measures about 5.2cm, cross section of femoral neck was 3.5cm, caput femoris to femoral neck axis base in lateral aspect of greater trochanter was10.1cm and cross section above the lesser trochanter to the lateral part of the greater trochanter was 8.4 respectively.[42]

In 2008, **Samaha. A.A** et al, undertook asymmetry and structural system analysis of the proximal femur epiphysis- osteoarticular anatomical pathology and reported that the value of femoral neck angle may fluctuate from 109^0 to 153^0 without predilection of race and gender, whereas the Wagner and Colleagues reported that the diaphysis femoral neck angle varies from 125^0 to 132^0.[43]

In 2008, **Saikia.KC** et al, did an anthropomertic study on hip joint in North Eastern region population with CT scan and suggested that the average angle of inclination was about 139.5^0 in the North Eastern populations.[44]

In 2009, **Toogood** et al, had described the proximal femoral anatomy and reported the average neck shaft angle as 129.23^0 by analysis 375 normal human femur bones.[45]

In 2009, **Bokariya.P** et al, did a study on anthropometry of femur in central Indian population by using 106 (58 right and 48 left) adult femora and measured with the sliding caliper and osteometric board. The aim of his study was to determine the measurements for obtaining foraminal index (FI), robusticity index (RI) and platymeric index (PI) and the objectives of the study was to evaluate the geometry of the femur of Central Indian population, to see the difference between right and the left bones and did a comparative study between their data and the data from the other areas. He observed that the robusticity index on right femur as 13.11± 0.93 and left side as 14.44±1.23cms, platymetric index on right side as 86.49±6.77cms and left side as 87.63± 7.34 cms and the foraminal index on right femur ranges between 31% to 61% and on left femur it ranges between 33% to 62%. The study concluded that the mean values of the length on right and left femur was statistically similar. However, the values of the right femora showed smaller values than the left femora.[7]

In 2009, **Mishra.A.K** et al, has undertaken a second look of implant design at rational for the upper end of femur and published that the implants of Western countries should be used in Indians only after a careful consideration. He also stressed that the implants used for fracture of Indian bones should be specific.[46]

In 2010, **Gargi.S** et al, analysed sex of femur and published the accuracy for differentiation of sex in males is 62.5% and in females is 62.9%.[47]

In 2010, **Desousa.E** et al, established the geometry of proximal femur in Brazilians. The study was performed by using 110 dry adult femora in Brazilians. Among the bones 49 belonged to right side and 61 to the left side. The study excluded the bones with osteosynthesis and those showed malformation or abnormalities that could affect its shape and structure. Bones were examined on roentgenographic analysis and scanned images. They obtained the measurements by graph pad instat software and autocad software. The study evaluated the parameters such as femoral neck width, femoral neck length, femoral head diameter, femoral axis length, off set and the neck shaft angle.

In this study the femora were also radiographed by using a diagnostic portable model FNX 200, with branded film, that measured about 30x40cm. At a distance of 100cm of the bulb chasis, the images were obtained by using a power of 75kV and 10mA. Then the radiographs were scanned. Measurements of right and left sides were obtained as follow: Femoral neck width (FNW) 30.96±2.94mm, femoral neck length (FNL) 30.1±4.3mm and 30.5±4.1mm, femoral head diameter (FHD) 31.1±2.7mm and 30.8±3.0mm, femoral axis length (FAL) 98.2+/-5.9mm and 97.4±7.13mm, off set 42.6±6.1mm and 42.0±5.6mm and the neck shaft angle (NSA) $132.0^0 \pm 7.2^0$ and $131.8^0 \pm 5.2^0$ respectively.[5]

In 2010, **Sen.R.K** et al compared the anatomical, radiographical and computed tomographed measurements of upper end of femur among an Indian population. He used dried femora (24 right and 26 left). Beginning from proximal to distal end, the femur was divided into 10 cross sectional levels. Using radiography and CT, the lateral anteroposterior, 45^0 external oblique diameter and 45^0 internal oblique diameter of medullary canal were measured at each level. The femur was kept over the broad/ film to reduce the magnification. The femoral head off set, femoral head diameter, collo diaphyseal angle, neck length were also measured. Vernier caliper was used for anatomical measurements. Comparison between three modalities was obtained by using Pearsons calculation coefficient. The result of this study showed that, the mean collo diaphyseal angle was 132^0, the mean diameter of femoral head was 45mm, the mean length of the neck was 63mm, the mean head off set of femur was 42mm. Here the dimension of endosteum gradually decreased from 1 to 10 levels in all 4 diameters, the endosteal dimensions showed different decreasing trends from 3 to 7 levels in the trochanteric area. In antero-posterior plane, the degrees was less marked and in the lateral plane it was more marked. When compared to the anatomical measurement at upper levels the medullary canal diameters were smaller as compared to the radiographic and CT measurements.

Radiographic distortion was higher at the level of the lesser trochanter in all 4 diameters. The distortion was minimal at the levels 7 to 10 and generally lesser on radiography than on CT. At level 3, based on the lateral diameter 37 femora were classified as small, medium and large. Remaining 13 femora were excluded from the analysis due to its larger size. Measurements of anteroposterior diameter was higher than the lateral diameter. This study concluded that the implant geometry and surface finishing had an important role in cementless femoral prosthesis implant production.[6]

In 2010, **Zalawadia.A** et al, observed femoral neck anteversion in Indian population. The study aimed to detect the average angle of femoral neck anteversion. Fifty female femora, among that 27 right and 23 left and 42 male femora (22 right and 20 left), in all total 92 unpaired dry femora were used for the study. Here the specimen was placed at the corner of a horizontal surfaced glass board so that the condyles in the distal end rested on its surface. At the edge, the horizontal limb of a goniometer was fixed. Along the head and neck axis of the femur, the anteversion was measured. The study resulted that in males the average anteversion on right side was $21.23^0 \pm 0.30^0$ and $14.3^0 \pm 0.38^0$ on the left side. In females the average anteversion on right side was $20.87^0 \pm 0.36^0$ and $11.02^0 \pm 0.34^0$ on left side.

In five bones, the retroversion was observed 6.5%, 20.5% of the bones ranging between 0 to 10^0, neutral or almost neutral version were noted in five bones, 33.6% of the bones were in the range of 10^0 to 15^0, while above 15^0 there were 36.9% of bones. [48]

In 2011, **Baharuddin.M.Y** et al, had done a Morphological study of proximal femur in Malay population. The measurement s were taken from 120 right and left hips and he excluded abnormal body mass index (BMI) , previous femoral injury, pregnant women, had CT scan performed previously within 6 months prior, wearing various prosthesis or implants. The data of four parameters such as femoral head diameter, neck shaft angle, femoral neck width and femoral neck length were collected and by analysis of the data collected, he concluded that usually Dynamic hip screw with the neck shaft angle of 135^0 was generally used but for Malay population it may not suit because the average neck shaft angle for males was about 132^0 and for females 130^0 respectively. This study also emphasised the importance of the measurements of upper end of femur, especially the femoral neck length and width, collo diaphyseal angle which particularly varies from other populations. The study also gives good information to the clinicians and the engineers in the development of implants.[10]

In 2011, **Ravichandran.D** et al, did a study on proximal femoral geometry in Indians and its clinical applications by using 578 unpaired femora by measuring with goniometer and vernier caliper and he explained the geometry of proximal femur without determining the age and sex of the bones. The study reported that the average collo diaphyseal angle was about 126.55^0, the neck length was about 3.19cm and the mean width was about 3.1cm and he concludes that the current available dimensions of Western implants used in the orthopaedic surgeries does not match the proximal femoral dimensions of Indians and there was a need for modification of the implants.[3]

In 2011, **Murlimanju.B.V** et al, had done an osteometric study of the upper end of the femur and its clinical application. The study was to identify the geometrical parameter of head and neck of the femur in Indians. The study comprised of fifty dry bones. Superior and inferior head length, femoral head diameter, supero-inferior and antero-posterior diameter of the neck and the superior and inferior length of neck were measured by using vernier caliper. The study showed that the superior and inferior head length as 30.8±3.6 and 21.2±3mm, the mean diameter of femoral head was 41.5±2.8mm, the antero-posterior and supero-inferior femoral neck diameter was 23.9±2.9 and 30.2±2.5mm, the mean superior and inferior length of femoral neck was 22.3±3.1 and 31.2±4.1 respectively. This study enlightens the orthopaedicians as well as anthropologists.[49]

In 2012, **Srimathi.T** et al, made a study on femoral neck anteversion and its clinical correlation aimed to measure in both the sides and both the sexes in Indian population. 164 dried adult femora (88 right and 76 left) with 81 male bones and 83 female bones were used. Bones with significant arthritic or bony deformities were excluded. The angle between transcondylar line into the centre head neck line was measured by using goniometer.

The result was documented as the mean value was 10.13^0 in the left and 9.49^0 in the right femora with a standard deviation of 1.50 and 1.66 respectively. So the angle in the left femur was higher. The mean value in the female was 9.79^0 and 9.78^0 in the male with a standard deviation of 1.54 and 1.70. So the value of female bones was higher. About 54.2% of bones were in the range of 8^0-10^0, 15.8% bones had angle more than 12^0, 21.9% were in the range of 10^0-12^0, 7.9% bones were in the range of 0^0-8^0. Most bones showed the range of 8^0-10^0 of anteversion. The study concluded that increase in the femoral anteversion angle was associated with cerebral palsy, perthes diseases, postural defects, anterior poliomyelitis, external tibial torsion, apparent genu valgum, intoing, flat foot. Decrease in the femoral anteversion angle was associated with rickets, chondrodystrophy, toing out.[4]

In 2012, **Limwei.L.V** et al, demonstrated a new method for the measurement of the parameters of proximal femora in males. In this study, they used fifty one healthy chinese males. Patients with the history of hip disease or femoral diseases were excluded. An average age of the males 70.5 years, ranging from 66-75years were selected for the study. To identify the morphological difference in the bone, the samples were divided into two groups according to their age. 66 to 70 years old samples were subjected as group A and group B subjects with 71 to 75 years old. Bone mineral density, height and weight of the subjects were noted as a part of the morphological parameters. By using clinical QCT, all subjects were scanned and eight morphological parameters were measured such as femoral head diameter by fitting the contour of oral head of femur with a circle at anterior view, superior view and right view, height of femoral head, collo diaphyseal angle. Off set, femoral thickness, diameter of neck, and neck length.

The result from the above data collected showed, that the weight of group A and B are 60.5881±7.5759 and 57.3654±7.6780, height of group A and B are 161.852±5.1744 and 163.8462±4.7777, bone mineral density (BMD) of group A and B are 0.865±0.1046 and 0.8083±0.1246, head diameter was 47.6483±1.7448 and 48.8720±2.1887, off set for group A and B was 37.8201±3.9379 and 38.2476±4.5263, collo diaphyseal angle was 126.0779 ±6.3039 and 126.896±6.2753, femoral thickness was 9.4549±0.7371 and 9.2150±0.9931, neck diameter was 34.8184±3.2642 and 37.2116±2.6514 and neck length was 89.4211±6.443 and 92.2888±7.1455 respectively. This study concluded that, a significant difference was found between two measurement in off set, height of the head, neck diameter, neck length and femoral thickness.[11]

In 2013, **Nallathamby.R** et al, did a comparative study of neck shaft angle of femur in South Indian population on 100 dry femora. Among these 100 dry femora, 52 were of the female and 48 were of the male and 49 belonged to right side and 51 belonged to the left side. In this study the gender of the bone was determined by the weight of the bone, prominence of muscular markings and the caput condylar length.

The result of this study showed that the mean value of collo diaphyseal angle was 134.56^0. The mean angle for males was 134.2^0 and for females 134.8^0. The standard deviation was 5.97 and 6.06 respectively. The mean value was 133.8 on right side and 135.2 on left side and the standard deviation was 6.39 and 5.55 respectively. The study concluded that the mean collo diaphyseal angle for females was little higher for the males but statistically no differences was found. The mean collo diaphyseal angle of the right femur was lesser than that of the left but no statistical significance was found.[2]

In 2013, **Kaur.P** et al, conducted a study on collo diaphyseal angle on radiography in the North West Indian population. The study was performed in 280 patients on the pelvic radiographs. All the patients were aged between 20 to 50 years. For the purpose of the study, patients, AP view and pelvic X-ray in supine position were taken. Anthropometric measurements were taken bilaterally on picture archiving and communication system (PACS) with digital caliper. The measurements and observations were made under the radiologist’s guidance. History of the patients like age, sex and the presenting complaints were also collected. The results were statistically analysed.

The result showed that the mean collo diaphyseal angle in females on left side was $120.16^0 \pm 2.51^0$ and on right side it was $121.16^0 \pm 2.50^0$. The mean collo diaphyseal angle in males on left side was $121.33^0 \pm 2.36^0$ and on right side it was $121.63^0 \pm 2.41^0$. The mean collo diaphyseal angle of the total population on the left side was $121.13^0 \pm 2.44^0$ and on right side it was $121.39^0 \pm 2.46^0$. The study concluded that the collo diaphyseal angle does not have significant difference between both the sides and both the genders in the North West Indian population.[50]

In 2014, **Kamdi.A** et al, proposed osteometric parameters of the femur in Telangana region and aimed to correlate different geometrical parameters of the femur for forensic practise and anthrological studies. 40 femora (28 right and 12 left) of unknown sex were measured by using vernier caliper and osteometric board. First fixing the femur in the osteometric board in such a way that the two epicondyles touched the vertical wall; dorsal aspect of the femur in the upward direction. The highest point of the femoral head was made to touch the movable piece of the board. Between the deepest point on medial condyle and the highest point of the head, the maximum length of the bone was measured. Other parameters were measured by using vernier caliper. In case of the shaft, at right angle to the transverse diameter was measured to record the anteroposterior diameter of the upper segment of the shaft. The maximum elevation of linea aspera at mid shaft region, the antero-posterior diameter of middle segment of the shaft was measured. Approximately 4cms above the cartilaginous margin of the condyles, the antero-posterior diameter of the lower segment of the shaft was also recorded.

The study revealed that the mean length of the femur was 43.26cms (right side-43.19cm and left side- 43.28cm). Maximum length was 48.2cm and minimum length was 37.8cm. Mean antero-posterior diameter at the upper segment of the shaft was 24.67mm, mean at middle segment of the shaft was 25.1mm and of the lower segment of shaft it was 25.77mm. The study also specified that there was no significant difference between right and left side.[51]

5. DIFFERENTS METHODS USED TO MEASURE THE FEMORAL GEOMETRY:

In 1988, **Christopher.A.K** et al, measured neck shaft angle of the femur of plain radiographs (hip joint is exposed) of homozygous sickle cell patients by using an illuminator box, calibrated protractor, HB pencil and a transparent graduated measuring ruler (mm). With an interval of 2cm, he marked midpoints of three horizontal lines beginning from the upper end of the lesser trochanter that joins vertically passing medially above the greater trochanter. Again a line was drawn from distal end of the greater trochanter and the fovea in the centre of the femoral head, that crossed the vertical line. The angle was formed in the anterior aspect of the intertrochanteric line of the proximal end of the shaft. He placed the calibrated protractor on the radiograph directly which was already fixed on the illuminator box and recorded the measurements.[52]

In 1994, **Glur.C.C et al**, worked out the prediction of hip fractures from pelvic radiographs of osteoporotic fractures, in 190 women aged above fifty years. The geometrical values were recorded by using pelvic radiographs in 15-30 degrees of internal rotation of hips with a film focused at a distance of 100 cm in supine position and the beam centered on the symphysis pubis. All morphometric measurements were performed unilaterally.[53]

In 1996, **Robertson.D** et al, studied femoral deformity in adults with developmental hip dysplasia using computerized tomography and three-dimensional reconstruction and described the deformity associated with dysplasia. He was the first to use the technique to determine morphology of the upper end of femur in 24 Japanese adults with developmental dysplasia of the hip. Average models of the dysplastic femur was developed by their findings. As they studied on male and the female patients of heterogenous group with widely varying degree of subluxation without control group they could conclude only regarding the abnormalities of dimensions of the dysplastic femur and the shape on the basis of anatomical parameters analysed from the normal femora of Western populations.[54]

In 2000, **Kaneuji.A** et al, measured at saggital plane and coronal plane of reconstructed models in the three dimensional morphological analysis of proximal femora, using computer aided design system.[55]

In 2002, **Ziyal.T** has described the antropometry of Anatolion human femur by using a digital sliding caliper, an osteometric board and a tapeline to measure the length, diameter and the circumference of the femur. Goniometer was also used to measure the collo diaphyseal angle of the femur.[36]

In 2004, **Sighn.I.P**and**Bhasin.M.K,** A manual of biological anthropology suggested the measurement of geometry of the femur, they suggested that, soon after cleaning the bones it has be examined under day light. Then the bone was fixed in the osteometric board, by using vernier calliper the width of the narrowest part of the neck was measured and identified the midpoint of the neck of the femur. In the surface of the bone, the point was marked by the marker. Along the neck axis, a thread was fixed on both ends of the bone that defined the axis of the bone. Through the centre of the shaft of the bone another thread was mounted that defined the diaphyseal axis. Then by using a transparent protractor the angle at the meeting point of two threads was measured and the values were recorded. The neck shaft angle of the femur was defined by the angle between the neck and diaphyseal axis.[56]

In 2006**,Dong.X** et al, prepared a fully automatic determination of morphological parameters of upper end of femur from calibrated fluoroscopic images that particle filtering, he designed the algorithm of morphological parameters of the upper end of femur that fitted femoral head into sphere, fitted femoral shaft into cylinder and fitted femoral neck into round table. Anyhow, a lot of morphological information may miss in the fitted femoral head.[57]

In 2007, **Song.W.W** et al, within a sphere, he fitted a part of acetabulum of reconstructed model and the head of the femur. However, except these two, other parameters were not measured in this study.[58]

In 2008, **Chantarapanich.N** et al, measured proximal length of the femur and the femoral curvature which were reconstructed from CT images in his study. The geometrical assessment of femoral curvature was measured by a reverse engineering technique.[59]

In 2009, **Aroojaratham.P** et al, did a three dimensional morphometric study of the Thai proximal humerus- a cadaveric study is not applicable in vivo measurement.[60]

In 2010, **Sen.R.K** et al, had done a correlation between anatomic, radiographic and computerized tomographic measurements of proximal femur in 50 dried femora (24 right and 26 left) by using radiography which is commonly used for preoperative measurements of the femur dimensions but it has many limitations such as resolution, exact positioning and image distortion but computerized tomogram eliminatedsuch limitations and it provided three dimensional images. For anatomical measurements a caliper were used.[6]

In 2011, **Baharuddin.M.Y** et al, measured the geometry of proximal femur in Malay population and the measurements were taken from sixty subjects (30 males and 30 females) 60 right and 60 left hips. Pregnant women, abnormal body mass index (BMI), those who wearing prosthesis or implants were excluded in this study. Femoral geometry was measured by using four row multi slices CT scanner (somatom, volume zoom, siemens) at 12.0mm table field per rotation, 3.0mm thickness and operated at 120kV and 90mAs and the patients were asked to lay in the supine position and their feet is stabilized by a specifically designed wood jig to standardize the feet position during image acquisition.[10]

In 2011, **Murlimanju.B.V** et al, evaluated the morphological and topographical anatomy of nutrient foramina in human upper limb long bones and their surgical importance, measured diaphyseal nutrient foramens in all the bones by using an elastic rubber band that is applied around the upper end of the nutrient foramen and photographic images were taken by digital camera.[49]

In 2012, **Linwei.L.V** et al, measured the morphological parameters of upper end of the femur. Eight morphological parameters were measured in this study, during the measurement process two auxiliary lines were created, which were neck axis and the shaft axis of the femur. Neck axis: Firstly, the narrow end of neck of the femur was cut and fixed the cross section within a circle. The neck axis was defined as the connection of the head centre and the circle centre. Shaft axis of proximal femur: In most old people, the shaft of the femur was curved, but the shaft axis of the upper end of femur was straight, so 25mm below the inferior edge of the lesser trochanter and the inferior edge of the lesser trochanter was cut off and fixed the contours of cross section within a circle. Shaft axis of proximal femur was defined as the connection of two circle centres.[11]

6. FEMORAL FRACTURES:

In 1993, **Faulkner** et al, predicted hip fracture by simple measurements of femoral morphometry and concluded that femoral fractures are very important health burden that regards medical costs, disability and even death.[61]

In 1993, **Felson** et al, their study further stated that including the geometry of proximal femur, the body mass index also plays an important role in fracture risk.[62]

In 1995, **Boonen** et al said that some of the parameters of the femur play an important role in an increased risk of fracture. In addition to that, a longer hip axis length was also associated with fracture risk.[13]

In 1995, **Peacock** et al, found that the collo diaphyseal angle values are higher in fracture cases.[63]

In 1996, **Pinilla** et al, done a study on femoral fracture and documented that the femoral parameters including femoral neck axis, hip axis length, femoral head width, femoral neck width, femoral neck shaft angle, intertrochanteric width are related to the mechanical strength of upper end of femur. These morphometric measurements were also involved in the higher incidence of the fracture of hip. The collo diaphyseal angle shown by the biomechanical test does not correlate with the strength of femoral neck.[64]

In 1999, **Ravn** et al, said that within the bone, the stress depends on the morphometric arrangement and on the direction of bone and by the materials of which the bone was made and also the size of the force applied.[65]

In 1999, **Simmermacher.R.K** et al, studied the anthropometric variation of the neck of the femur between races to predict osteoporosis related hip fractures. Only one dimension of hip geometry was separated by neck length of the femur. To detect the risk of fracture, the neck dimension was also assumed. The independent predictors of hip fractures were hip axis length, cortical thickness, bone mineral density and neck shaft angle.

In the transitional bones, between the neck and the shaft of the femur, the intertrochanteric fracture occurs. Both the greater and the lesser trochanters are involved in this fracture. Transition bones are composed of trabecular and cortical bone. Posteromedially calcalfemorale is formed by these bones, which provide the capacity to distribute the stresses of weight bearing. This fractures does not disturb the blood supply of the head of the femur. Osteonecrosis is uncommon and the complications like non-union is also uncommon as the transitional bone is highly vascular.

The intertrochanteric fracture classification was based on the stability of fracture. In 1949 Evans introduced this classification. His classification differentiates the stable and unstable fractures. He said that the stability of the fractures depends on the integrity of posteromedial cortex. The instability increased with the comminution of the fracture, presence of a reverse oblique fracture pattern and the fracture extended to the subtrochanteric region. According to Evans, the intertrochanteric fractures were classified into i) stable and reverse, ii) standard oblique fracture, iii) oblique fracture (unstable).[66]

In 2000, **Rosso** and **Minisola** found that there was difference in the incidence of hip fractures from country to country.[67]

In 2001, **Testi** et al, said that a larger collo diaphyseal angle was associated with fracture risk.[68]

In 2004, **Gregory** et al, assessed the shape of the upper end of femur and its relationship to hip fracture. The study revealed that the shape of the upper end of femur is a major risk factor for hip fractures of the neck of the femur, regardless of bone mass or strength.[69]

7. IMPLANTS USED:

In 1991, **Bridle** et al, explained the commonly used implants in India. They are

i) Intramedullary devices. Eg: Proximal femoral nail (PFN).

ii) Extramedullary devices. Eg: Dynamic hip screw (DHS).

In the last two decades, DHS was a major implant used for fixation in the proximal fractures. But in 20% of cases it may have problems of cutting through, implant failure, screw giving away from shaft, rate of fixation failure and penetration of the joint by the screw. Whereas intramedullary devices had an advantage of being close to the weight bearing axis have taken over as the modality for the fixation of these fractures.

For fixation of intertrochanteric fractures, the intramedullary devices are becoming popular. Dynamic hip screw fixation needs a larger surgical wound exposure, anatomical reduction and more handling of soft tissues and it may also caused an increased morbidity because of the infection and blood loss. Moreover, biomechanically intramedullary devices are more superior. In hip joint, the bending force on implants is decreased by an intramedullary device when compared to the laterally fixed side- plate. Especially in elder patients, this is an advantage in whom the treatment goal was a sudden full-weight bearing mobilization.

In case of pretrochanteric fractures, the gamma nail fixation was recommended. But in 8 to 15% of cases reported a cut out of leg screw occurs, which was a serious complication. An anti rotation screw was present in the proximal femoral nail and that was fixed in the neck of the femur which was helpful to avoid the cervicocephalic fragments rotation during weight bearing. PFN was the latest implant used in the intertrochanteric fracture management. This implant had many advantages such as load transfer was more efficient as it was intramedullary, maintains controlled impaction, stress was less transferred and implant failure was also less because of the shorter lever arm, loss of blood was less and also the soft tissue dissection was less.

Proximal femoral nail is available in two varieties: i) the long cannulated variety and ii) the standard variety. The standard variety of PFN consist of a 240mm long nail. The lower part of nail was in 10, 11 or 12 mm diameter and 17mm in diameter at it proximal part. Between the two parts, the angle measures about 6 degrees and it lies 11cm from the top of the nail. Through the proximal part two screws were inserted. The neck screw was 11mm and anti-rotation screw was 6.5mm. Distal locking can be dynamic or static. To reduce the stress, the nail was specially shaped at its tip.

In a modified PFN, the proximal part of the implant was reduced to 14mm from 17mm, the neck diameter screw was reduced from 11mm to 8mm, the length of the device was reduced to 18mm and the rotational screw reduced to 6mm from 6.5mm. This study concluded that the small diameters are suited for Indian population.[70]

In 1993, **Faulkner.K.G** et al, found that the femoral neck width influences the prediction for the eventuality of the fracture.[61]

In 1995, **Baumgartner.M.R** et al, documented that, femoral geometry influences the risk of hip fracture. So various parameters like femoral neck length, femoral neck width and collodiaphyseal angle were assessed. The result showed that the FNL, FNW and CDA could be used with bone marrow density measurement to picture the risk of hip fracture.[71]

In 2001, **Kim.W.Y** et al, suggested that proper positioning of the screw was very important because, the biomechanical and anatomical studies revealed that the weakest part of the implant was the supero medial quadrant of the head of the femur.[72]

In 2009, **Song.P.U** et al, said that initially most of the implants are designed on the basis of measurements in Caucasian population. So use of such implants in Asian population causes problems or complications due to the mismatch of implant size for Asian population.[73]

MATERIALS AND METHODS

a) Source of data:

The present study was carried out in the department of Anatomy from June 2014 to August 2015 on 90 dry femora (45 right femurs and 45 left femora) from the Department of Anatomy, Sree Mookambika Institute of Medical Sciences, Kulasekharam.

b) Study design:

Descriptive study.

c) Total sample size of the study:

90 dry bones (45 right femora and 45 left femora).

Sample size calculation:

By literature reference (an analysis of Anatolion human femur Anthropometry) by Ziylan.T, Murshid.K.A.

The highest standard deviation in left femur is noted as 4.7, $\sigma = 4.7$

using the formula $\frac{4\sigma^2}{E}$.E=0, Hence the sample size is 90.

a. Inclusion criteria:

Bones of both sides of either sex.

b. Exclusion criteria:

Any femur that showed a significant malformation and abnormality that could affects its shape and structure.

c. Parameters to be studied:

- Angle between neck and shaft of femur in degrees.
- Head transverse diameter in millimetres.
- Neck transverse diameter in millimetres.
- Head vertical diameter in millimetres.
- Neck vertical diameter in millimetres.
- Proximal breadth in millimetres.

d) Materials used:

- Goniometer.
- Coloured thread.
- Sliding caliper.

Fig:2, Sliding caliper, Goniometer and coloured thread.

e. Procedure:

Angle between neck and shaft

1. By using the coloured thread, axis of the neck was determined.
2. The thread divides the anterior surface of the neck into two equal halves.
3. In the mid sagittal plane over the anterior surface, the axis of the shaft was marked using the same thread.
4. Then the angle between the neck and shaft is measured using the goniometer.

Head Transverse Diameter

Transverse diameter of head is measured by sliding caliper as the maximum diameter of head in the transverse plane.

Fig:4, Measuring Transverse Diameter of Head using Sliding Caliper.

Neck Transverse diameter

Transverse diameter of neck is measured, minimum diameter of the neck of the femur in antero- posterior direction is measured using a sliding caliper.

Fig:5, Measuring Transverse Diameter of Neck using Sliding Caliper.

Head Vertical diameter

Vertical diameter of head is measured by using sliding caliper by measuring the maximum diameter of head in vertical plane.

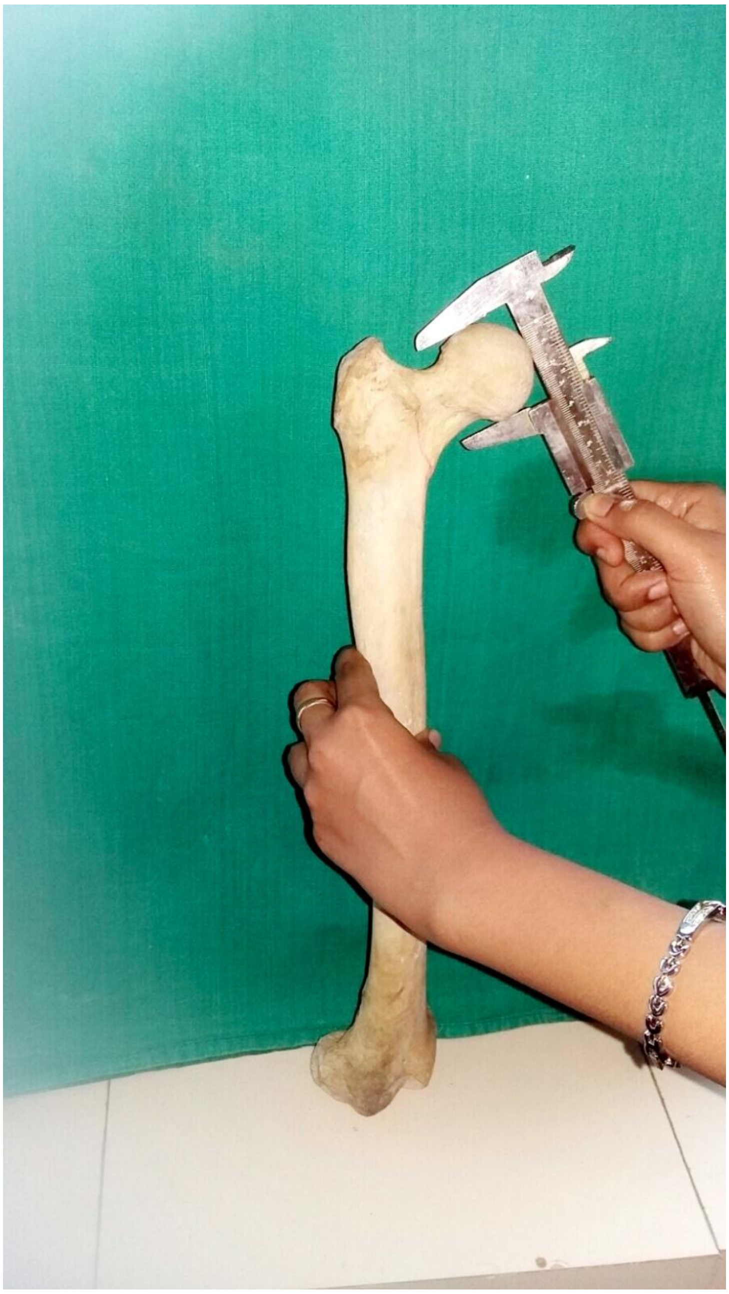

Fig:6, Measuring vertical Diameter of Head using Sliding Caliper.

Neck Vertical diameter

The vertical diameter of the neck is the minimum diameter of the neck of the femur at supero- inferior direction and it is also measured using a sliding caliper.

Fig:7, Measuring Vertical Diameter of Neck using Sliding Caliper.

Proximal Breadth

By using the sliding caliper, the maximum width between the head of the femur and the greater trochanter is measured.

Fig:8, Measuring Proximal Breadth using Sliding Caliper.

f) Statistics :

The data was collected and entered in a master chart. The statistical contents like arithmetic mean and standard deviation were found. In order to test various hypothesis to see the difference between the measurements of both the sides, mean was tested by using ‘t’ test.

All the statistical calculations were done through SPSS (Statistical presentation system software) of window version 10.0 SPSS.

In all the cases if the calculated ‘t’ was more than that is given in the ‘t’ table, the test was significant at the appropriate probability level and if the calculated ‘t’ was less than or equal to table value, t was said to be insignificant.

P-< 0.05 is significant.

P-> 0.05 is insignificant.

Fig:3, Measuring Neck Shaft Angle using Goniometer.

RESULTS

The femoral measurements were studied on 90 bones (45 right and 45 left femora) from the Department of Anatomy, Sree Mookambika Institute of Medical Sciences, Kulasekharam. The measurements of the bones on the right side and the left side were subjected to statistical analysis to evaluate the significance.

Method of analysis:

1. Analysis was done using Pearson's correlation.
2. Pearson correlation are applied to test the difference between femur of the right and left side.
3. Bar diagrams are used to represent the data.
4. p value less than 0.005 is considered statistically significant.

Table:1

DISTRIBUTION OF BONES

BONES	RIGHT SIDE	LEFT SIDE	TOTAL
Number of bones	45	45	90

Table 1: Shows the distribution of bones. By literature reference, the sample size was calculated and accordingly a total of 90 bones were studied. In this study, to identify the difference between femur of right and left sides, the bones are distributed in to 45 on each side.

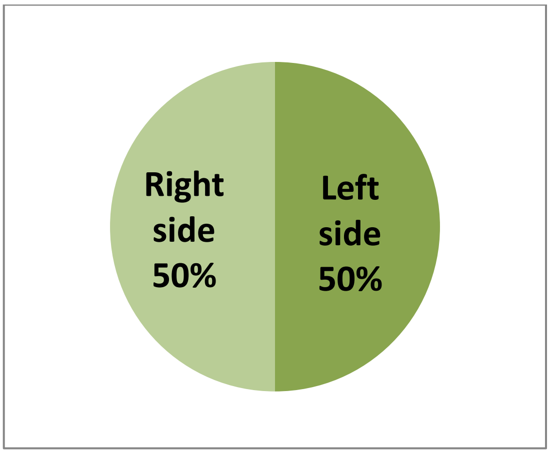

Fig:9, Distribution of Bones.

Table:2

NECK SHAFT ANGLE OF LEFT AND RIGHT SIDE

Neck shaft angle (NSA)	**Left side**		**Right side**		**t value**	**p value**
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	126.15	4.22	127.20	2.43	-1.44	0.152

Table 2: Shows the difference between the neck shaft angle of femur on right side and left side. It has been observed that the mean neck shaft angle the on left side was 126.16±4.22 degrees and on the right side was 127.20±2.43 degrees. The difference in the mean neck shaft angle on right side and left side was found to be statistically insignificant (p value: >0.05).

Figure:10

DIFFERENCE BETWEEN NSA OF LEFT AND RIGHT SIDE

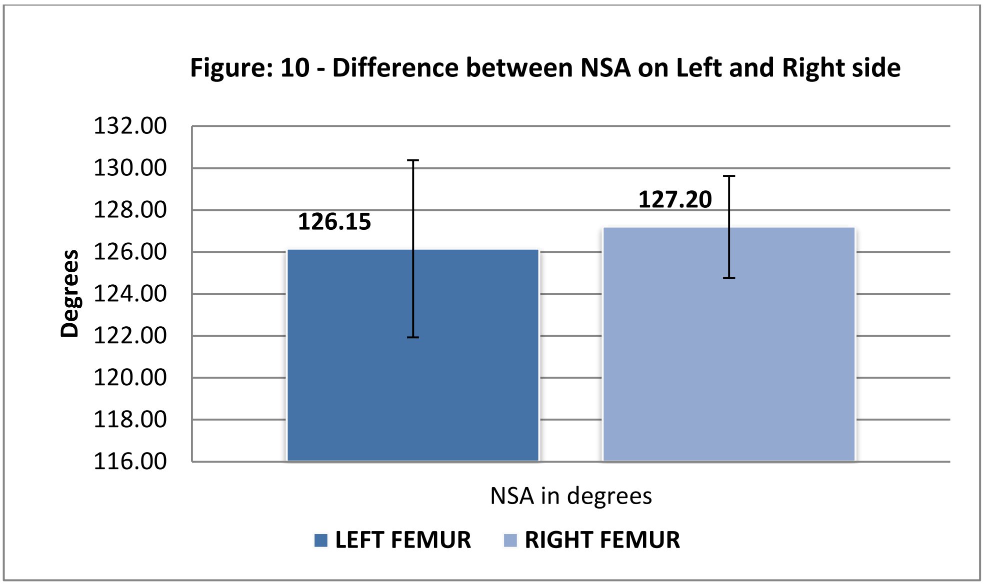

Figure 10: Represents the difference between neck shaft angle of femur on left and right side. It shows that the average value of neck shaft angle on left side was 126.15 degrees and on right side it was 127.20 degrees.

Table:3

TRANSVERSE DIAMETER OF HEAD ON LEFT AND RIGHT SIDE

Head transverse diameter (HTD)	**Left side**		**Right side**		**t value**	**p value**
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	33.31	3.79	33.88	2.46	-1.847	0.399

Table 3: Shows the difference between the head transverse diameter of the femur on the right and the left sides. Here, the mean value and the standard deviation on left side was 33.31±3.79 and on the right side it was 33.88±2.46 respectively. As p value is >0.05, there was no significant difference.

Figure: 11

DIFFERENCE BETWEEN HTD OF LEFT AND RIGHT SIDE

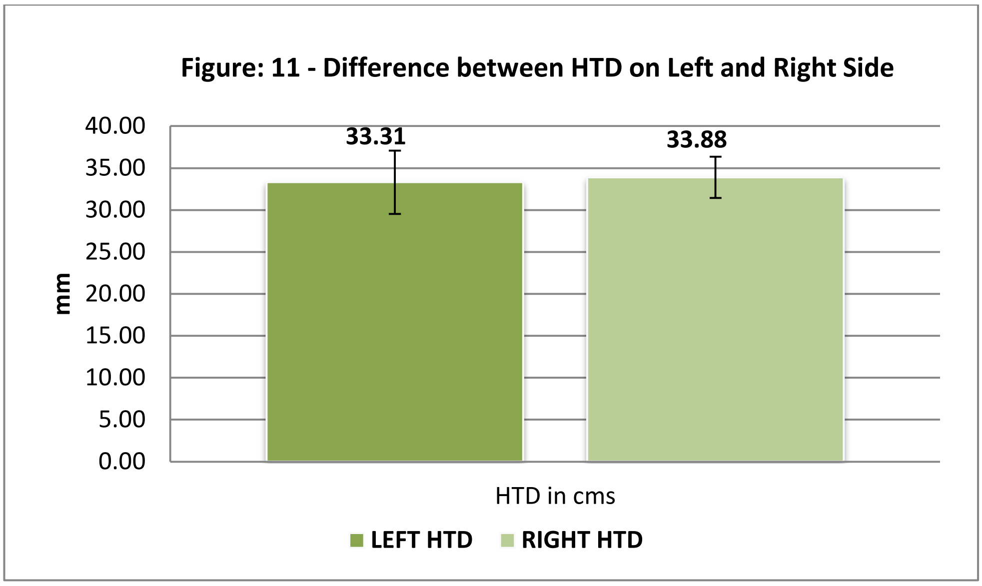

Figure 11: Shows the difference between head transverse diameter. The average value of HTD on left side was found to be 33.31mm and that of the right side it was 33.88mm.

Table:4

TRANSVERSE DIAMETER OF NECK ON RIGHT AND LEFT SIDE

Neck transverse diameter (NTD)	**Left side**		**Right side**		**t value**	**p value**
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	17.49	2.09	18.11	2.00	-1.42	0.157

Table 4: Shows the difference between neck transverse diameter of 45 femora on left side was 17.49±2.09 and that of the 45 femora on right side was 18.11±2.00 respectively. The difference in the mean neck transverse diameter on right and left side was found to be statistically insignificant (p value: >0.05).

Figure:12

DIFFERENCE BETWEEN NTD OF LEFT AND RIGHT SIDE

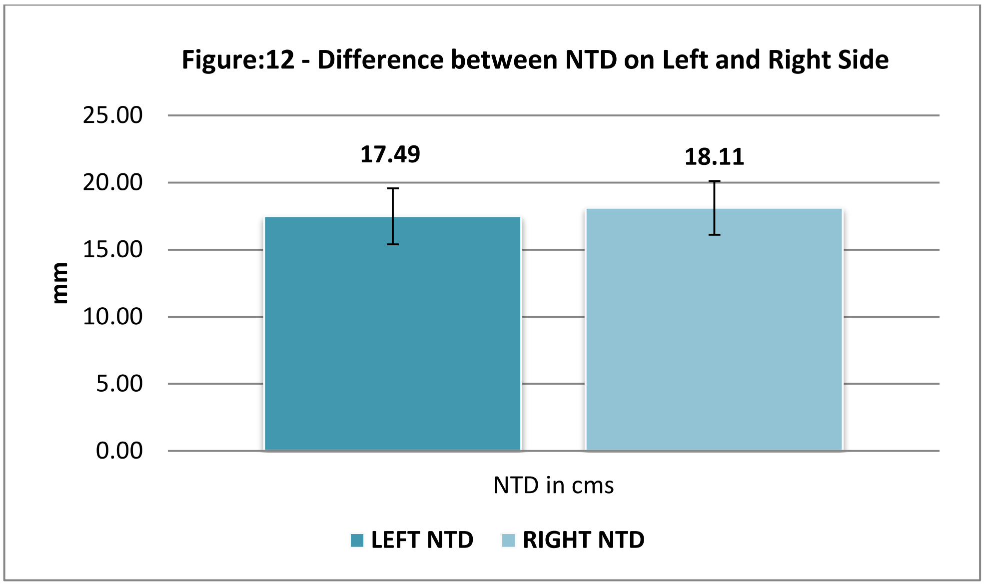

Figure:12, Shows the difference between neck transverse diameter of the left and right side. The average neck transverse diameter on the left side was 17.49mm and on the right side it was 18.11mm.

Table:5

VERTICAL DIAMETER OF HEAD ON LEFT AND RIGHT SIDE

Head vertical diameter (HVD)	Left side		Right side		t value	p value
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	32.12	2.00	32.87	2.53	-1.56	0.122

Table 5: Shows the difference between head vertical diameter of femur on the right and the left sides. The values of head vertical diameter on the right side was higher than on the left side but statistically no significant difference was found, as the p value was >0.05. The mean value of head vertical diameter on right side showed 32.87±2.53 and 32.12±2.00 on left side.

Figure:13

DIFFERENCE BETWEEN HVD OF LEFT AND RIGHT SIDE

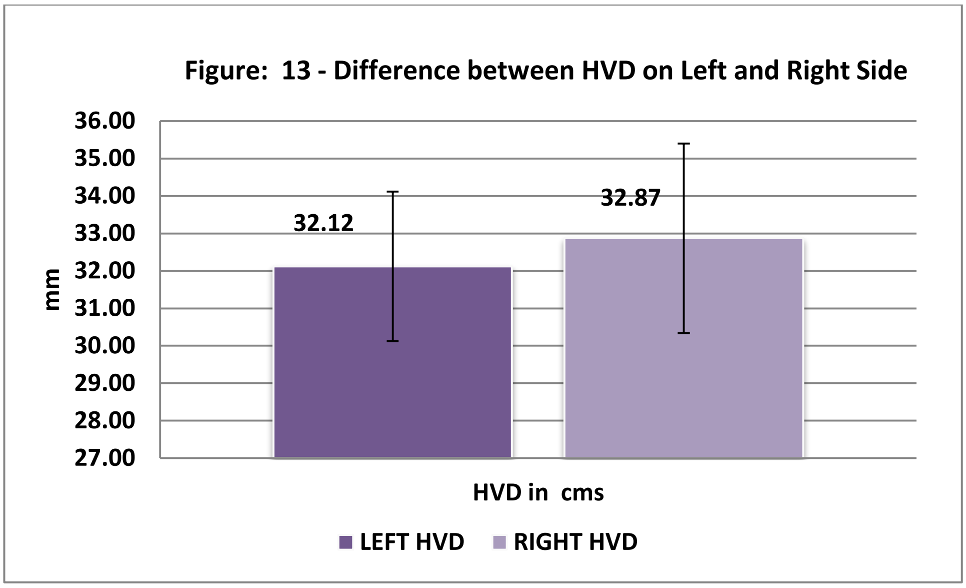

Figure 13: Shows the difference between head vertical diameter on the left side and the right sides. The average head vertical diameter on left side was 32.12mm and on right side it was 32.87mm.

Table:6

VERTICAL DIAMETER OF NECK ON RIGHT AND LEFT SIDE

Neck vertical diameter (NVD)	Left side		Right side		t value	p value
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	24.52	3.27	25.72	3.31	-1.705	0.092

Table 6: Shows the difference between vertical diameter of neck on right and left sides.These results show that the mean and the standard deviation of neck vertical diameter on the left side was 24.52±3.27 and on the right side it was 25.72±3.31.The values obtained in the study was found to be insignificant as p value was >0.05.

Figure:14

DIFFERENCE BETWEEN NVD OF LEFT AND RIGHT SIDE

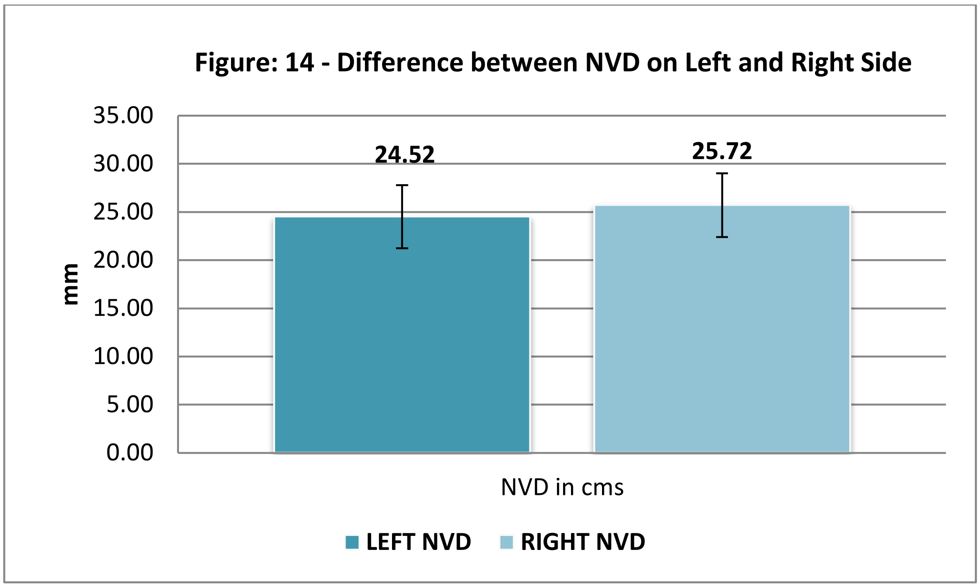

Figure 14: Shows the difference between neck vertical diameter on left and right sides. The average value of neck vertical diameter on left side was found to be 24.52mm and on the right side it was 25.72mm.

Table:7

PROXIMAL BREADTH OF RIGHT AND LEFT SIDE

Proximal breadth (PD)	**Left side**		**Right side**		**t value**	**p value**
	Mean	**S.D (±)**	**Mean**	**S.D (±)**		
	78.03	5.71	79.04	7.21	-0.734	0.465

Table 7: Shows the difference between the proximal breadth of femur on right and left sides. The mean proximal breadth on left side was found to be 78.03±5.71 and 79.04±7.21 on right side. The difference in proximal breadth on right side and left side was found to be statistically insignificant (p value:0.465).

Figure:15

DIFFERENCE BETWEEN PB ON LEFT AND RIGHT SIDE

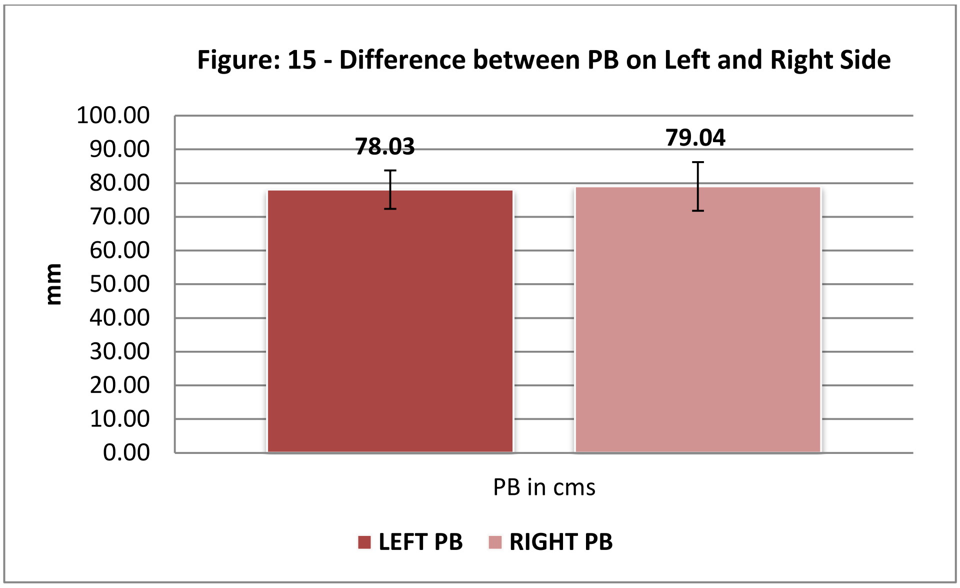

Figure 15: Shows the difference between proximal breadth on left and right side. The average value of proximal breadth on left side was found to be 78.03mm and on the right side it was 79.04mm respectively.

DISCUSSION

In the past few decades, researchers worldwide have used various methods to measure the bones. They have measured mechanically on the cadaveric bone as well as in patients by Roentgenography, Ultrasound, Computerised tomography and Magnetic resonance imaging. Earlier studies revealed that the measurements vary in population and the methods adopted.

This study was carried out to evaluate the morphometry of the femur, to find the difference between the right and the left side for designing Orthopaedic implants used in the treatment of fracture of femur. There is an increase in the incidence of injuries such as fracture of neck of femur. Treatment of those fractures uses implants which are based on the measurements of upper end of femur.

Neck shaft angle(Table:2)

In our study, the mean value of neck shaft angle on left side was $126.16^0 \pm 4.22^0$ and on the right side it was $127.20^0 \pm 2.43^0$. The difference in the mean neck shaft angle on right and the left side was found to be statistically insignificant (pvalue: 0.152). The average value of neck shaft angle on left side was 126.15^0 and on right side it was 127.20^0.

Ravichandran.D et al (2011)[3] studied proximal femoral geometry and concluded that the average neck shaft angle was 126.55^0, which is almost similar to the values obtained in our study. Not many Indian studies are available with respect to the proximal femur dimensions.

Kate (1968)[22] worked on 1000 femora and found the average neck shaft angle to be 128.4^0. Issac.B et al (1993)[27] found the average neck shaft angle as 127.5^0. Toogood et al (2009)[45] in their study on proximal femoral anatomy in the normal human population have reported the average angle as 129.23^0. Our results are almost similar to that of Kate, Issac and Toogood et al.

Saikia.K.C et al (2008)[44] has reported the average neck shaft angle in North Eastern population as 139.5^0. Nallathamby.R et al (2013)[2] worked on 100 dry femora in South Indian population and found the average neck shaft angle to be 134.6^0. Our results differ largely from that of Saikia.K.C and Nallathambhy.R et al.

Head transverse diameter (Table:3)

The difference between the head transverse diameter of femur of the right and the left sides. Here, the mean value and the standard deviation on left side was 33.31±3.79 and the mean head transverse diameter on right side was 33.88±2.46 respectively. As the p value is 0.399, there was no significant difference. The average value of HTD on left side was found to be 33.31mm and on the right side it was 33.88mm.

Nidugala.H et al (2013)[74] studied morphometry of femur in South Indian population and concluded that the head transverse diameter on right and the left sides was 35.31±2.90 and 36.81±3.79 respectively, which was almost similar to our result.

Desousa.E.B et al (2010)[5] studied proximal extremity of femur and found that the average head transverse diameter on right side was 31.1±2.7 and on the left side it was 30.8±3.0. In our study, the values are almost similar to Desousa.E.B et al. But Ziylan.Tet al (2002)[36] quoted that in Anatolion population, the average HTD was 44.7±4.1 on right side and 44.3±3.3 on left side. The results reported by Ziylan.T et al were contrasting to the values obtained in our study. It may be due to the variation among the population.

Neck transverse diameter (Table:4)

The difference between neck transverse diameter of 45 femora on left side was observed as 17.49±2.09 and 45 femora on right side was 18.11±2.00 respectively. The difference in the mean neck transverse diameter on right and left side was found to be statistically insignificant (p value: 0.157).The average neck transverse diameter on left side was 17.49mm and on the right side it was 18.11mm.

Ziylan.T et al (2002)[36] studied an analysis of Anatolian femur and reported that the values of neck transverse diameter on right side was 26.3±3.1 and on left side it was 25.5±2.7, the results obtained by Ziyal.T et al was contrasting to our results. This may be due to variation in the population.

Head vertical diameter (Table: 5)

The difference between head vertical diameter on femora of right and left side. The values of head vertical diameter on right side was higher than left side but statistically no significant differences were found, as the p value was 0.122. The mean value of head vertical diameter on right side showed 32.87±2.53 and on the left side it was 32.12±2.00.The average head vertical diameter on left side was 32.12mm and on the right side it was 32.87mm.

Nidugala.H et al (2013)[74] did a study on morphometry of femur in South Indian population and revealed that the head vertical diameter on right side was 39.85±3.55 and on the left side was 41.75±3.48. So the result obtained by Nidugala.H et al differs greatly when compared to our study.

Neck vertical diameter (Table:6)

The difference between neck vertical diameter on right and left side. These result shows that the mean and the standard deviation of neck vertical diameter on left side was 24.52±3.27 and on right side it was 25.72±3.31. It was found that the p value was 0.092, which is insignificant. The average value of neck vertical diameter on left side was found to be 24.52mm and on the right side it was 25.72mm.

Ziylan.T et al (2002)[36] reported the morphometry of Anatolion femur and quoted the result of neck vertical diameter on right side as 45.2±4.0 and on left side as 43.4±3.2. Due to the variation in the population of our study, the results of Ziylan.T et al, was contrasting to our study.

Proximal breadth (Table:7)

The difference between the proximal breadth on femora of right side and left side. The mean proximal breadth on left side was found to be 78.03±5.71 and that on the right side was 79.04±7.21. The difference in proximal breadth of right side and left side was found to be statistically insignificant (p value:0.465).The average value of proximal breadth on left side was found to be 78.03mm and on right side it was 79.04mm respectively.

Nidugala.H et al (2013)[74] studied the metric assessment of femur in South Indian population and concluded that the proximal breadth on right side was 76.74±5.73 and that on left side was 79.78±6.71. The values obtained in this study was almost similar to our study.

Strecker et al (1997)[31] stated that the mean values of right and left femora were found to be similar, although the left femur generally showed larger values than on the right, they were not much significant.

Parsons (1914)[18] proposed that no significant bilateral differences were found in bones.

Ziylan.T et al (2002)[36] found, a significant difference in the head vertical diameter of femur on right and left sides.

SUMMARY

A descriptive study was carried out on 90 dry femora from the department of Anatomy, at Sree Mookambika Institute of Medical Sciences, Kulasekharam. The morphometric difference between right and the left femora were assessed. The data was collected in a fixed time.

The study revealed that there is no statistical significant difference found in the measurements on the right and the left femora. Therefore the mean values of NSA, HTD, NTD, HVD, NVD and PB will enlighten the biomechanical engineers to take a revolutionary step towards altering the implants designs to suit our needs.

CONCLUSION

The study has shown that there is no significant difference between the values obtained on the right and the left femora.

In this study the mean value of Neck shaft angle, Head transverse diameter, Neck transverse diameter, Head vertical diameter, Neck vertical diameter and proximal breadth on the right and left femora have no statistical significant differences.

It is commonly accepted that the statistical analysis of Morphometry of femur among various populations reveals a large amount of variation due to the fact that the morphometric measurements of femur from different countries are likely to be affected by variations in climate, hereditary, diet and other geographical factors related to life style.

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Morphometric analysis of upper end of femur.

Table showing the parameters of femur on both side.

Sl no	side	NSA in degrees	HTD in mm	NTD in mm	HVD in mm	NVD in mm	PB in mm
1.	L	130.2	35.2	17.1	24.2	25.2	84.4
2.	L	126.7	22.6	15.7	23.8	18.2	63.5
3.	L	129.3	28.7	12.3	29.3	18.3	69.8
4.	R	128.3	34.1	21.2	33.5	23.1	81.2
5.	R	129.6	28.8	18.5	31.3	17.8	76.5
6.	R	128.2	35.1	19.6	33.8	19.3	79.4
7.	R	124.5	35.1	18.5	34.2	22.1	80.1
8.	L	127.8	30.4	18.1	29.1	19.8	67.3
9.	L	125.2	34.3	19.1	30.4	18.7	82.3
10.	R	127.2	35.2	20.1	35.2	21.2	80.8
11.	R	128.3	34.3	17.5	34.5	26.1	76.5
12.	R	127.5	35.1	20.2	34.3	21.3	80.2
13.	L	126.3	22.6	3.2	27.4	23.4	69.2
14.	R	129.5	36.2	21.2	35.1	26.3	83.3
15.	L	135.1	33.2	15.2	29.6	19.5	77
16.	L	128.3	35.2	16.1	32.5	18.3	70.4
17.	R	124	35.3	17.4	36.5	31.1	88
18.	R	130.3	33.1	14.4	32.2	28.1	82.2
19.	R	123	35.2	19.6	33.3	29.2	81.5
20.	L	129.6	33.3	20.2	33.5	18.2	68.6
21.	L	128.2	33.8	16.7	26.3	19.2	69.8
22.	L	129.2	35.7	17.7	32.3	20.5	68.2
23.	L	129.8	35.2	16.7	32	25.7	79.5
24.	L	118.7	33.2	20.7	31.1	26.1	81.1
25.	R	128.9	31.5	16.3	29.5	27.7	73.2
26.	R	129.8	33.1	16.3	32.8	26.3	83.2

27.	R	126.5	36.2	18.6	35.2	30	90.3
28.	R	124.8	33.2	19.8	32.2	26	80.2
29.	L	130.5	33.3	15.1	30.2	25.3	67.4
30.	R	123.5	34.2	18.5	34.3	31.4	88.7
31.	R	130.5	30.2	15.6	29.5	22.5	79.3
32.	R	127.1	33.7	18.7	33.1	25.8	80.2
33.	L	128	22.4	14.3	32	19.1	70.9
34.	L	131.3	31.7	16.8	31.1	19.5	69.5
35.	R	131.1	29.5	12.5	30.6	24.9	68.2
36.	L	127.6	36.5	18.8	26.9	19.7	73.7
37.	R	124.3	36.2	19.8	36	29.7	84
38.	L	129.8	36	20.1	29.3	23.2	73.6
39.	R	123.9	34.1	18.5	35.5	30.1	88.7
40.	L	130.6	29.4	14.9	32.1	24.3	71.1
41.	L	127.4	35.2	17.1	31.1	23.5	80.9
42.	R	125.9	37.2	17.4	32.3	26.5	79.9
43.	L	127.3	33.2	16.3	30.1	23.4	79.4
44.	R	131.2	33.5	13.1	31.3	26.4	78.9
45.	L	122.5	33.5	14.8	32.7	23.6	77.4
46.	L	120.5	35	16.8	31	24.1	80.1
47.	L	120.1	32.3	13.4	32.1	24	79.5
48.	R	129.8	34.1	16.9	34.5	28.3	82.3
49.	R	130.5	35.2	15.5	34.2	27.2	84.5
50.	L	126	31.6	18.9	30.3	25.5	74.4
51.	L	125.6	31.8	15.2	29.2	24.2	80.2
52.	R	128.7	34.2	14.8	34.1	26.5	86.1
53.	R	125.5	36.3	17.2	34.2	29.6	80.4
54.	R	125.7	35.4	18.1	35.2	30.1	82.1
55.	L	129.4	35.3	19.2	29.2	21.3	68.4
56.	L	126.9	28.1	12.9	30.4	19	75.5
57.	R	126.8	29.3	18.5	29.1	28.2	81.2
58.	R	128.3	34.1	20.2	34.3	28.1	80.3
59.	L	128.5	33.5	18.4	27.1	18.6	79.1

60.	L	116.8	36.6	20.4	32.4	28.1	84
61.	L	119.2	39.4	20.5	33.5	30.6	84.3
62.	R	126.1	35.2	18.5	34.5	26.5	84.5
63.	R	125.5	35.1	18.7	36.3	29.2	88.4
64.	L	120.5	36.9	19.3	32.4	27.5	88.5
65.	R	129.5	35.3	21.2	35.1	28.5	80.1
66.	R	129.5	34.5	20.1	36.5	29.7	85
67.	L	126.8	36.3	15.5	31.2	17.2	74.3
68.	L	117.3	35.5	17.2	32.3	24.2	84.2
69.	R	125.9	29.3	16.5	33.4	23.1	73.5
70.	R	124.3	36.2	19.3	34.2	30.4	84.2
71.	L	128.3	35.8	14.1	31.9	29.2	82.3
72.	R	124.3	36.1	17.2	32.2	31.7	77.3
73.	R	124.9	36.1	17.1	34.6	33.1	79.8
74.	L	127.7	33.6	16.9	32.1	25.5	80
75.	R	129.1	26.4	18.2	34.2	28.5	78.8
76.	L	128.6	33.3	17.3	33.3	18.1	71.2
77.	R	130.3	34.5	20.2	35.1	27	76
78.	L	129.4	33.1	17.4	32.2	20.3	69.3
79.	R	128.9	34.4	19.2	35.2	30.5	84.3
80.	R	124.2	34.6	19.5	34.1	26.8	80.6
81.	L	122.3	34.1	14.9	31.3	23.2	78.5
82.	L	125.3	35.4	18.4	34.5	27.3	87.6
83.	R	124.3	28.3	17.5	27.1	17.8	68.4
84.	L	130	35.3	18.6	32.2	22.5	68.2
85.	R	129.4	35	19.1	33.2	27.1	77.5
86.	L	125	39.2.	15.6	32.6	25.2	79.7
87.	R	125	35.2	18.2	35.2	29.2	88.7
88.	L	118.4	38.4	19.5	35.4	28.4	80.3
89.	L	123.5	30.7	15.6	33.2	25.5	79.8
90.	L	121.6	33.4	16.8	33.3	23.4	82.3