THESIS ABSTRACT

TITLE: "A CADAVERIC EVALUATION AND MORPHOMETRIC ANALYSIS OF KNEE JOINT WITH ITS CLINICAL IMPLICATIONS"

The anatomical concept of the knee has always been regarded as a significant in medical practices for decades. The knee is the largest synovial joint in the body, consisting of three distinct joints which include the patellofemoral joint, medial tibiofemoral joint & lateral tibiofemoral joint. It is partially separated by the compartments which collectively forms it functionally a complex 'hinge' joint and structurally a compound, complex and condylar variety of synovial joints.

A thorough anatomical knowledge of normal structure and functions, however, can be used to predict or understand the immediate impact of a specific injury and the secondary effects on intact structures. The unpredictability of forces transmitted through the knee complex sources from the gravity, weight bearing forces, muscles, ligaments, and other passive soft tissue structures. Any alteration in the anatomy of knee can substantially influence these forces and can have a dramatic impact on the functioning of the knee joint. Damage to the tibiofemoral joint or patellofemoral joint can result from either a large rapid load or the accumulation of smaller repetitive loads. Therefore, understanding and studying of both the primary and secondary restraint anatomical structures of knee are important in order to gain a full appreciation for the pathogenesis of knee disorders.

Several researchers have attempted to comprehend the anatomical study of knee, structures related to the knee joint, and their clinical implications on overall physical health in discrete. A few studies have attempted to comprehend the understanding of knee joint as a whole. However, there are no studies largely taken as a whole on cadaveric analysis of knee joint to enhance clinical ability to recognize the morphometric analysis, morphological anatomical variations and surgical and non-surgical anatomical and clinical inter co-relations. Therefore, providing the cadaveric evaluation of the knee joint and concepts of morphometric and morphological analysis of the structures surrounding to the knee joint in relation to the age, gender and symmetry will significantly help the modern practitioners to tackle the problems of knee illness and physical health and thus, reduce the burden on society. Furthermore, despite various studies are present, the lack of disaggregated anatomical data enbloc on knee remains a significant challenge across the world. So, it is very significant to conduct a

cadaveric based study that can focus on assessing the anatomical knowledge of knee joint and thereby, enhance the knowledge pertaining to the cause, clinical features, proper diagnosis, faulty biomechanics of joint, surgical reconstruction procedures, surgical replacement procedure, graft procedures, in designing of properly matched prostheses, and in the various other management of physical and knee-related illness. This suggests scope of the study is multifold and hence the need for the present study.

The present study was conducted as a direct observational cross- sectional study carried out after obtaining approval from the Institutional Ethics and Research Committee Medical College Baroda, Gujarat. The primary objective of the research was to describe the functional outcome of the cadaveric evaluation and morphometric analysis of knee joints during the period from the 2018 to 2021 in a cadaver donated to the cadaveric laboratory. The specimens for the present study included of adult human cadaveric lower limb of known age, gender and side available during the study period in the various department of Anatomy. Total Ninety properly embalmed and formalin fixed lower limb of adult cadavers were selected for the study. The study group comprised of sixty-two males and twenty-eight females with equal number of right and left sided as forty-five right sided and forty-five left sided. The specimens were taken for a sample as per available in the department and only suitable for the study after obtaining permission from the head of the department.

The detailed history of cadavers was collected from the record register. Every previously embalmed formalin fixed knee joints were dissected. The Limbs were observed for any changes or for any of the exclusion criteria. All the available specimens were checked for its inclusion and exclusion criteria. Only specimens which satisfied our study criteria were dissected. Dissection was done under the guidance and supervision of guide; any required intervention was carefully taken and observations were made, Vernier calipers with a minimum count of 0.01 mm and a cloth measuring tape was used to record all the measurements. The morphometric linear measurements of the knee joint, including patellar articular surfaces, articular surfaces on the lower end of the femur, the upper end of the tibia including articular and non-articular area, and various intra articular and extraarticular ligaments were measured, morphology and morphometric analysis of menisci, morphometric analysis of cruciate ligaments. morphometric analysis of collateral ligaments, morphometric analysis of patellar ligament, morphometric analysis of oblique popliteal ligament and any other morphological and morphometric variations related to any soft tissues, muscles,

ligaments, and bones related to knee joints were thoroughly observed, studied in detail and recorded. The data was analyzed and recorded.

The following metric parameters of patella and patellar ligament of knee are measured with the digital vernier caliper:

Height/Length of patella: Measuring the linear distance between superior border of patella and apex of patella

Width of patella: Measuring the linear distance between medial and lateral border of patella.

Thickness of patella: Measuring linear distance between anterior surface and median ridge on posterior surface of patella.

Width of lateral articular facet: Measuring the maximum width from the lateral border to the median ridge of patella.

To describe the Width of medial articular facet: Measuring the maximum width from the medial border to the median ridge of patella.

Length of patellar ligament: Measuring the linear distance between the apex (non-articular posterior surface) of patella and tibial tuberosity.

Width of patellar ligament: Measuring the linear distance between the two margins/borders of patellar ligament.

Thickness of patellar ligament: Measuring the linear distance between the anterior and posterior surface of patellar ligament at proximal and distal part.

For the classification of patella, we followed the guidelines made by Wiberg;
Type I: there are roughly equal medial and lateral facets
Type II: most common: medial facet is only 1/2 size of lateral facet
Type III: medial facet is so far medial that the central ridge is barely noticeable

Bicondylar width of femur (BCWF): Measuring the maximum distance between the medial and lateral femoral condyle in transverse plane.

Medial femoral condyle antero-posterior diameter (MFCAPD): Measuring the maximum distance between anterior and posterior surface of medial femoral condyle.

Medial femoral condyle transverse diameter (MFCTD): Measuring the maximum distance between medial and lateral surface of medial femoral condyle.

Lateral femoral condyle antero-posterior diameter (LFCAPD): Measuring the maximum distance between anterior and posterior surface of medial femoral condyle.

Lateral femoral condyle transverse diameter (LFCTD): Measuring the maximum distance between medial and lateral surface of lateral femoral condyle.

Intercondylar notch width of femur (ICNWF): Measuring the maximum distance between medial and lateral surface of intercondylar notch of femur posteriorly.

Intercondylar notch length of femur (ICNLF): Measuring the maximum length of intercondylar notch of femur.

Bicondylar width of tibia (BCWT): Measuring the maximum distance across both tibial condyles in transverse plane.

Distance from tibial condyle to tibial tuberosity: Measuring maximum distance from tibial condyle to tibial tuberosity.

Medial tibial condyle antero-posterior diameter (MTCAPD): Measuring the maximum distance between anterior and posterior borders of superior articular surface of medial tibial condyle.

Medial tibial condyle transverse diameter (MTCTD): Measuring the maximum transverse diameter of superior articular surface of lateral tibial condyle.

Lateral tibial condyle antero-posterior diameter (LTCAPD): Measuring the maximum distance between anterior and posterior borders of superior articular surface of lateral tibial condyle.

Lateral tibial condyle transverse diameter (LTCTD): Measuring the maximum transverse diameter of superior articular surface of lateral tibial condyle.

Total anteroposterior measurement of intercondylar area (TOTAL AP ICA): Measuring the maximum distance between anterior and posterior borders of upper end of tibia.

Anteroposterior measurement of anterior intercondylar area (AP AICA): Measuring the maximum distance between anterior border of intercondylar area to a line joining intercondylar eminence.

Anteroposterior measurement of posterior intercondylar area (AP PICA): Maximum distance between a line joining intercondylar eminence and posterior border.

To describe the transverse measurement of intercondylar area (TD ICA): The maximum transverse diameter at following three levels: a) anterior part b) middle narrow part – at the level of intercondylar eminence c) posterior part

Morphological variation in the different shape of medial menisci: Crescent shape: thin anterior, posterior horns and thin bodies, Sickle shape: thin anterior, posterior horns and thick bodies. C-shape: Menisci which resembled sided C, Sided U-shape: Menisci which resembled sided U, Sided V-shape: Menisci which resembled sided V.

Morphological variation in the different shape of lateral menisci: Crescent (semilunar) shape: thin anterior, posterior horns and thin bodies, C-shaped: Menisci which resembled sided C, Discoid (circular): When the meniscus covers the tibial plateau circularly.

To describe the length of menisci: Outer circumference measurement from apex of anterior horn to the apex of posterior horn of menisci.

Width of menisci: Anterior One-third, Middle one-third, Posterior one-third

To describe the thickness of menisci: Anterior One-third, Middle one-third, Posterior one-third

Length of superficial medial collateral ligament: The maximum linear distance from the medial epicondyle of the femur to its lower attachment on the tibia.
Width of superficial medial collateral ligament: maximum width of the ligament in middle part.
Length of deep medial collateral ligament:
Length of Menisco-femoral ligament: Maximum distance from its femoral insertion to the centre of its insertion on the medial meniscus.
Width of Menisco-femoral ligament: Maximum distance between the two borders of ligament.
Length of Menisco-tibial ligament: Maximum distance from its tibial insertion to the center of its insertion on the medial meniscus.
Width of Menisco-tibia ligament: Maximum distance between the two borders of ligament.
Length of lateral collateral ligament: Maximum linear distance from the lateral epicondyle of femur to its lower attachment on the fibula.
Width of lateral collateral ligament: Maximum width of the ligament in the middle part.

Length of anterior cruciate ligament: Measure the maximum linear distance from tibial and femoral attachment.

Width of anterior cruciate ligament: Measure maximum transverse linear distance of ligament.

Length of posterior cruciate ligament: Measure the maximum linear distance from tibial and femoral attachment.

Width of posterior cruciate ligament: To measure maximum transverse linear distance of ligament.

Length of transverse ligament: Measure the maximum linear distance from its attachment to anterior horn of medial meniscus to anterior horn of lateral meniscus.

Width of transverse ligament: Measure the maximum linear distance from its anterior to posterior border.

Length and width of oblique popliteal ligament:

Any other findings: We observed the various other morphological variations in relation to the knee joint:

1) Variations in relationship to the pes anserinus was observed for the: a) Structures constituting in insertion pattern of pes anserinus b) mode of insertion of pes anserinus c) site of insertion of pes anserinus

2) Variations in relationship to the presence and absence of os fabella under the head of lateral head of gastrocnemius was observed and analyzed for its maximum length and maximum width.

3) Variations in relationship to the plantaris muscle was observed during the study; therefore, we made an attempt maximum length and width of belly of muscle; maximum length and width of tendon of plantaris muscle; and maximum length of plantaris from its proximal to distal attachment was measured.

The overall results and data interpretation of the morphometric analysis and cadaveric evaluation of knee highlights that various range of anatomical structure related to the knee joint was highly significant and an exhaustive anatomical discussion attempted to drawn though beyond the scope. The results of the beneficiaries reveal that analyzing the functional outcome observed significantly different in the various aspects of the morphometric linear measurements of the knee joint in a symmetrical pattern and among gender. The result data was categorized and analyzed in accordance with the objectives of the study under the following broad headings:

A. Morphometric results on the bones contributing in formation of the knee joint;

B. Morphological and morphometric analysis of menisci of knee joint;

C. Morphometric analysis and anatomical variations observed in the various ligaments of knee joint;

D. Other anatomical variations in relations to the evaluation of cadaveric knee joint.

The findings of the analysis were done based on SPSS. The t-test, was applied to find the cadaveric evaluation and morphometric analysis of knee joint, the association between the selected demographic variables and correlations between the symmetrical sexual dimorphism

Results from our findings summarized as:

- There was no significant difference in the dimensions of all the measurements of the patella, the patellar ligament for symmetrical pattern and gender comparison except in the thickness and width of patella. we hypothesize that the predominant use of one limb may result in better muscle tone on that side, which might have a direct effect on the shape of the patella within quadriceps femoris tendon.

- The larger stress exerted on the lateral facet may contribute to a higher risk of developing patellofemoral arthritis in our study because the majority of our cadaveric specimens have identical width of MAF and LAF.

- The frequency of patellar alta (ratio>1.5) is observed higher in the present study. The use of the Insall-Salvati ratio to determine the patellar position measured by cadaveric dissection methodology may be less appropriate to the Indian populations in which squatting, sitting cross-legged, and kneeling are customs and culture in daily life. We proposed that the normal range of the ratio for the habitual squatters among Indian populations may be higher than the existing normal range.

- The difference in means in both the variables, right, left and males and females were observed to be statistically insignificant for all the metric parameters of distal end of femur except for the bicondylar width of femur and intercondylar notch width of femur.

- The difference in means in both the variables, right, left and males and females were observed to be statistically insignificant for all the metric parameters of upper end of tibia.

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- The anatomical profile of bones forming knee was observed smaller in females. Highlighting the necessity for population-specific prosthesis sizing particularly in Indian females.

- We observed the highest incidence of crescent shaped medial menisci. The second highest prevalence was observed sickle shaped medial menisci in 66 (73.33%) specimens. The equal proportionate incidence was observed with C- Shaped (22.22%) and Sided U shaped (4.44%). No any meniscus with sided V- Shaped was observed in any of the specimen in the present study.

- In the present study we observed the highest incidence of C-shaped (73.33%) lateral menisci. The second highest prevalence was observed in crescent shaped lateral menisci. The lowest incidence was observed with discoid (incomplete) shaped lateral menisci.

- Menisci encompass half to two-thirds of the articular surface of the comparable tibial plateau in the current study, with the lateral meniscus spanning more area than the medial meniscus. The results showed that the medial menisci had a longer outside circumference than the lateral menisci, which is statistically significant for both right and left sides. The anterior portion of the medial meniscus is found to be narrower, whereas the posterior third is the widest in terms of medial meniscus width. The width of anterior, middle, and posterior thirds and thickness of the anterior, middle, and posterior thirdsof medial meniscus were observed statistically insignificant for symmetrical and gender dimorphism.

- For the results of morphometric linear measurements of patellar ligament of knee. Mean difference in the variables, right sided, left sided, in males and in females for all the metric parameters were observed to be statistically insignificant.

- The superficial medial collateral ligament was the largest observed structure in the medial side of the knee. Our findings have the same opinion with those of previous literature, who have described it to be between 10 and 12 cm in overall length.

- Fibular collateral ligaments in all the specimens in this research analysis extended from the lateral epicondyle of the femur to the head of the fibula. Furthermore, no any morphological variability in terms of bifurcated, trifurcated ligament or double fibular collateral ligament was observed in any specimen of the present study. In addition, we observed the highly statistically significant difference between males and females for all the metric measurements of the lateral collateral ligament.

- The present study included morphometric measurements of the ACL and PCL as a whole unit extending from tibial to femoral attachment. The measurements were done in various angle of position of knee flexion and the maximum linear measurements were considered for the result. Any morphometric measurements in the present study were not observed to be statistically significant for the bilateral symmetrical pattern or sexual dimorphism.

- We observed the total incidence for the presence of transverse ligament in 85.55% specimen and total absence of ligament is observed 14.44%. The data analysis revealed that there had been few anatomic studies that explicitly addressed the occurrence of this structure.

- The present study observed prevalence of fabella bone was more common. Usual bilateral presentation was observed with more on right sided knee. Unilateral to bilateral presentation of fabella was observed as 1:2. Further, we observed the fabella bony only; no remarkable presence of cartilaginous fabella was observed. The fabella was observed closely in relation to the common fibular nerve in all specimens. The explanation for the increased occurrence in this study could be attributed to various behaviors originating from everyday routines in which Indians kneel more frequently. Furthermore, based on our findings, we may assume that the presence of the fabella was not associated to body side but is gender specific. Lack of anatomical knowledge about fabella bone can be missed as loose bodies in diagnosis in both clinically and radiological. Therefore, the study on fabella is of great important clinically to the orthopedic surgeon for differential diagnosis in knee pain and to the radiologist and anthropologist to understand evolutionary changes in knee joint.

- In the present study, morphometry and variations pertaining to unilateral double head of plantaris muscle was observed. Meanwhile, we suggest the present variation in the plantaris muscle observed was rarest and this anatomical knowledge can be useful in the fields including medicine, surgery and specially to the evolutionary biology and anthropology.

- This study highlights the several variants of the pes anserinus. The pes anserinus was formed by combined occurrence of mono-tendinous Sartorius, Gracilis and Semitendinosus (S/G/ST pattern) and reported to be the most common observed pattern forming PA in the present study. The Sartorius, Gracilis, Semitendinosus, accessory band of sartorius, accessory band of semitendinosus, another accessory band of semitendinosus (S,G,ST,aS,aST,abST pattern) in forming pes anserinus was

observed in 1(1.11%); these type of variations were not commonly seen and rare to exist. The findings of the study would assist in planning of surgical procedures in this area. The detail knowledge of this kind of variants is important in the planning and performing various surgical procedures by orthopedic surgeons and plastic surgeons.

- This study presents the rare case of long accessory band of semitendinosus inserting into the tendocalcaneus along with the tendon of plantaris muscle. The long accessory band was measured 46.6cm in length from the common muscular insertion and the width was measured as 0.4mm. The short accessory band measured with length of 19.2cm and width 8.0mm.The long accessory band was inserted into the tendocalcaneus along with plantaris muscle. As a result, the current study emphasizes the importance of operating surgeons understanding unusual anatomical variations of the semitendinosus muscle in order to avoid complications during procedures such as transplant surgeries and graft harvesting during reconstructive surgeries in order to practice efficient surgical procedures.

- We suggest that the greatest value of the present work is that it presents possibly the first such systematic cadaveric evaluation and morphometric analysis of knee joint en bloc.

- Female Indians had smaller dimensions than male Indians, and both had lesser aspect ratios than the Western population. Present study provides definite rationale for designing total knee prosthesis, especially a gender-specific design suitable for the Indian population.

- A systematic dissection module is developed for exploring the cadaveric knee in the present study.

The present study concludes that an anatomical knowledge of knee performs substantial corner, valuable services and social benefits to the mankind. Due to lack of sensitization in the awareness for body donation and decrease in availability of cadavers in the medical institutes has been a gross problem in the current scenario. Therefore, in modern era cadaveric study on Knee joint generate measurable and testable data based on estimates. The number of problems associated with the knee is increasing with obesity, sedentary and modern lifestyle and rate of people with physical knee disorders and young patients for joint replacement surgery is still alarming. This explains why in recent years researchers have attracted widespread

concern throughout the developing world and among the developed county community in general in the field of knee.

Despite the various methods that facilitate the study of knee joint including cadaveric study, bone study, CT scan study, MRI study, Intra operative study, several features enable us to consider the methodology together.

All of these are focused on analysis of knee and mere shows an important role in the various anatomical and clinical aspects of knee for providing the important data for the modern medical science and finally enclose an important role in beneficiary to the health services and society.

The conclusion of the study would help the surgeons to treat the physically ill, in a great many ways. Findings of the present study will try to bridge the gap that exists in the literature resources as. It can serve as a base for reference for any future research that will be taken upon the knee joint globally. Acknowledging the possible role of anatomical knowledge of the knee joint in the field of medical science, present data will aid the knowledge to the anatomist and leading surgeons to facilitate better health and community care. The overall results denote multifold highly specific correlation of surgical, anatomical, therapeutic, rehabilitation, evolutionary biology, anthropometry and comparative anatomy research field for the knee approaches, which denotes affected individual moderately can have favorable multidirectional attitude towards the knee illness.

KEYWORDS: Collateral ligaments, Cruciate ligaments, Femur, Fabella, Joint replacement, Knee Arthroplasty, Knee Joint, Lateral Menisci, Ligaments of the knee, Ligament reconstruction, Ligamentum patellae, Medial Menisci, Morphology, Morphometry, Patella, Pes anserinus, Tibia.