"CORRELATION BETWEEN GROSS ANATOMICAL AND RADIOLOGICAL EVALUTION FOR ATTACHMENTS OF MEDIAL AND LATERAL LIGAMENTS OF KNEE JOINT IN CADAVERS OF INDIAN ORIGIN"

Thesis submitted to

All India Institute of Medical Sciences, Jodhpur

In partial fulfillment of the requirement for the degree of

MASTERS OF SURGERY (MS)

ORTHOPEDICS

JULY 2020 **DR. LIKHITH RAM NAIK**

AIIMS, JODHPUR

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CERTIFICATE

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DECLARATION BY THE CANDIDATE

I hereby declare that this thesis entitled **"CORRELATION BETWEEN GROSS ANATOMICAL AND RADIOLOGICAL EVALUTION FOR ATTACHMENTS OF MEDIAL AND LATERAL LIGAMENTS OF KNEE JOINT IN CADAVERS OF INDIAN ORIGIN"** is a bonafide and original research work carried out in partial fulfillment of the requirementsfor the degree of Masters of Surgery in Orthopedics under supervision and guidance, inthe Department of Orthopedic Surgery, All India Institute of Medical Sciences, Jodhpur.

Date: 16|07|23

DR. LIKHITH RAM NAIK

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This is to certify that **DR. LIKHITH RAM NAIK** has satisfactorily completed his thesis entitled **"CORRELATION BETWEEN GROSS ANATOMICAL AND RADIOLOGICAL EVALUTION FOR ATTACHMENTS OF MEDIAL AND LATERAL LIGAMENTS OF KNEE JOINT IN CADAVERS OF INDIAN ORIGIN"** in partial fulfillment of the requirements for the Masters of Surgery in Orthopedics. He has donethe research work under my supervision and guidance. He has fulfilled all the requisites under regulations laid by the All India Institute of Medical Sciences, Jodhpur and no part of the thesis has been submitted to any other university.

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No one who achieves success does so without acknowledging the help of others. The wise and confident acknowledge this help with gratitude.

-Alfred NorthWhitehead

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DR. LIKHITH RAM NAIK

I

DEDICATE

THIS THESIS

TO MY

PARENTS AND

MY TEACHERS.

LIST OF ABBREVIATIONS

- sMCL - Superficial Medial Collateral Ligament
- POL - Posterior Oblique Ligament
- MPFL - Medial Patellofemoral Ligament
- LCL - Lateral Collateral Ligament
- PT - Popliteal Ligament
- LFC - Lateral Femoral Condyle
- ME - Medial Epicondyle
- LE - Lateral Epicondyle
- SD - Standard Deviation
- MAX - Maximum
- MIN - Minimum

SUMMARY OF THE PROJECT

Background: The purpose of this study is to examine the anatomical attachments of medial and lateral knee ligaments in Indian cadaveric knees. The goal was to compare the anatomical attachments of ligaments of the knee with radiographic locations obtained by various published methods, to assess the Inter-observer and Intra-observer correlation of radiographic methods for assessing the ligament attachments. This information is helpful while repairing and reconstructing knee ligaments.

Objectives: To compare the anatomical attachments (marked by cadaveric dissection) with the radiographically marked location of Medial and Lateral knee ligaments by described methods in the literature, for Indian knees.

Methods: 18 paired formalin-treated Indian cadaveric knees were dissected carefully to identify the medial knee ligaments i.e sMCL, POL, MPFL, and lateral knee ligaments i.e LCL, PT. The femoral, tibial and fibular attachment sites of knee ligaments were identified and marked with colour markers followed by hammering the metal beads or nails into their attachment sites. Fluoroscopic images were taken for the knees and anatomical measurements and radiographical measurements were measured based on commonly used methods in literature on Indian knees.

Results:

LCL

Lateral view:

BY PEITRINI et al. [3]

Qualitatively, the femoral attachment of the lateral collateral ligament (LCL) was located in the posterodistal quadrant.

Quantitatively, it was 7.52±1.09 mm (Max=9.75, Min=5.89) from the lateral epicondyle.

With regard to the osseous reference lines, it was 4.5±5.51 mm (Max=6.3, Min=-12.8) posterior to the posterior femoral cortex extension line (Y-axis) and 6.09±4.38 mm (Max=-1.06, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Regarding the distal fibular attachments of the lateral collateral ligament (LCL) with osseous reference line on the fibula, it was located at a distance of 11.29±4.70 mm (Max=19.5 Min=4.62) distally from the fibular styloid apex and 5.23±3.56 mm (Max=13 Min=0.53) distally from the line drawn intersecting the most anterior and proximal aspects of the fibular head.

BY KREMEN et al.[9]

With regard to osseous reference lines, it was estimated to be 70.15±14.45% (Max=91.3, Min=48.3) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 10.77±17.98% (Max=35.5, Min=-17.2) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction

Anteroposterior view:

BY PEITRINI et al.[3]

The lateral collateral ligament (LCL) was located 26.91±5.64 mm (Max=35.4, Min=16) proximal to the femoral condylar line and 31.15±7.01 mm (Max=40.5, Min=16) distal to the tibial plateau line.

PT

Lateral view:

BY PEITRINI et al.[3]

Qualitatively, the femoral attachment of the popliteal tendon was located in the posterodistal quadrant.

Quantitatively, it was 9.02±2.49 mm (Max=16.1, Min=5.66) from the lateral epicondyle.

With regard to the osseous reference lines, it was 11.81±5.90 mm (Max=0.8, Min=-20.2) posterior to the posterior femoral cortex extension line (Y-axis) and 5.10±5.67 mm (Max=5.33, Min=-13.7) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

BY KREMEN et al.[9]

With regard to osseous reference lines, it was estimated to be 52.47±15.70% (Max=84.3, Min=31.8) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 29.62±22.93% (Max=79.1, Min=-14.4) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction.

Anteroposterior view:

BY PEITRINI et al.[3]

The popliteal tendon was located 16.53±5.63 mm (Max=29.5, Min=10.4) proximal to the femoral condylar line.

sMCL

Lateral view:

BY WIJDICKS et al.[4]

Qualitatively, the femoral attachment of the superficial medial collateral ligament (sMCL) was located in the anterodistal quadrant.

Quantitatively, it was 7.37± 1.44mm (Max= 10.1, Min= 4.57) from the medial epicondyle.

With regard to the osseous reference lines, it was 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm (Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Regarding the distal tibial attachments of the superficial medial collateral ligament (sMCL) with osseous reference line on the tibia, it was located at a distance of 66.87±16.06 mm (Max=98.9 Min=44.3) distally from the medial tibial slope line and 1.78±4.60 mm (Max=6.94 min=-7.65) posteriorly from the mid diaphyseal axis of the tibia.

BY KK ATHWAL et al.[8]

With regard to the osseous reference lines, it was 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm (Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

BY HARTSHORN et al.[6]

Qualitatively, the femoral attachment of the superficial medial collateral ligament was located in the anteroproximal quadrant.

With regard to the osseous reference lines, it was 4.79± 5.19mm (Max= 13.44, Min=-5.41) anterior to the posterior femoral cortex extension line (Y-axis) and 1.81± 5.78mm (Max= 9.9, Min=-6.69) proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

BY WIJDICKS et al.[4]

The Superficial medial collateral ligament was located at 27.27± 5.23 mm (Max= 36.6, Min= 19) proximal to the femoral condylar line and 72.09± 14.20 mm (Max= 99.1, Min= 52.6) distal to the tibial plateau line.

POL

Lateral view:

BY WIJDICKS et al.[4]

Qualitatively, the femoral attachment of the Posterior oblique ligament was located in the posterodistal quadrant.

Quantitatively, it was 12.9±3.37 mm (Max= 16.6, Min= 6.2) from the medial epicondyle.

With regard to the osseous reference lines, it was 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

BY KK ATHWAL et al.[8]

With regard to the osseous reference lines, it was 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

BY WIJDICKS et al.[4]

The posterior oblique ligament (POL) was located at 28± 5.8 mm (Max= 40.1, Min= 20.9) proximal to the femoral condylar line.

MPFL

Lateral view:

BY WIJDICKS et al.[4]

Qualitatively, the femoral attachment of the medial patellofemoral ligament (MPFL) was located in the anteroproximal quadrant.

Quantitatively, it was 7.34± 2.06 mm (Max= 11, Min= 3.97) from the medial epicondyle.

With regard to the osseous reference lines, it was 0.52± 4.42 mm (Max= 5.66, Min=-9.4) anterior to the posterior femoral cortex extension line (Y-axis) and 6.02± 7.17 mm (Max= 15.7, Min=-7.06) proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

BY WIJDICKS et al.[4]

The medial patellofemoral ligament (MPFL) was located at 31.46±9.68 mm (Max= 52.1, Min= 14.5) proximal to the femoral condylar line.

Conclusion: This is the first study done on cadavers of Indian/Asian origin to evaluate ligament insertions and also the first to provide a comparison with previously published literature. Our study has assessed the published radiographic methods for the localization of knee ligaments and compared the cadaveric attachments with their derived points of attachments, we have noticed that none of the methods accurately depicts the exact attachment point of any ligament.

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INTRODUCTION

The knee joint is one of the largest joints in the body. It joins the leg and thigh bilaterally and is an essential component of efficient bipedal movements such as walking, running, and jumping. Because of its anatomical structure, exposure to external pressures, and the functional demands imposed on it, it is the joint that sustains injuries the most often. The knee joint plays a significant part in weight-bearing and is the joint that sustains injuries the most frequently. Injuries may be caused by a number of different mechanisms, including direct trauma, repetitive microtrauma (such as tendinitis or bursitis), or overuse.

The structures that surround the knee joint serve to stabilize it. These structures may be divided into three categories: osseous structures, extraarticular structures, and intraarticular structures. Although a lot of attention has been paid to the ligaments in the knee, it is important to note that the ligaments alone are not adequate to keep the knee stable; the supportive action of the related muscles and tendons is also necessary.

The patella, the distal femoral condyles, and the proximal tibial plateaus or condyles are the three components that make up the osseous structures of the knee. Although it is often referred to as a hinge joint, the knee is considerably more complex than that description suggests. In addition to flexion and extension, the motion of the knee also includes a rotating component.

The synovium, capsule, collateral ligaments, and musculotendinous units that span the joint are the key extraarticular structures that sustain and influence the function of this joint. The quadriceps mechanism, the gastrocnemius muscle, the medial and lateral hamstring groups, the popliteus muscle, and the iliotibial band are the primary musculotendinous units.

The medial and lateral menisci, as well as the anterior and posterior cruciate ligaments, are the most important structures that are located inside the joint itself. Many different roles, some of which are recognized and others of which are just hypothesized, have been attributed to the menisci. These tasks include the deepening of the joint, load-bearing or weight-bearing, nutrition, shock absorption, deepening of the joint, and stability of the joint. The cruciate ligaments serve not only as joint stabilizers but also as axes around which rotational motion, both normal and pathological, may occur. They help to govern the tibia's medial and lateral rotation on the femur, as well as the forward and backward motion of the tibia on the femur, and they limit the forward and backward motion of the tibia on the femur.

The primary extraarticular static stabilizing elements are the joint capsule and the collateral ligaments surrounding the joint. A sleeve of fibrous tissue known as the capsule surrounds the joint and extends from the patella and patellar tendon at the front of the joint to the medial, lateral, and posterior parts of the joint. The components of the capsule, coupled with the medial and lateral extensor expansions of the quadriceps muscle, are the primary structures responsible for joint stability anterior to the transverse axis of the joint.

In particular, the capsule is strengthened by the collateral ligaments, the medial and lateral hamstring muscles, the popliteus muscle, and the iliotibial band posteriorly to the transverse axis. The medial patellofemoral ligament is more significant for patellar stability. It extends from the patella to the medial femoral epicondyle and is located close to the intersection of the middle and superior thirds of the patella.

The most frequent knee ligament injury is one that affects the medial (tibiofemoral) structures of the knee, which are commonly referred to as the medial collateral ligament. Studies conducted in the past have shown that the primary structures responsible for maintaining the stability of the medial tibiofemoral joint are the superficial medial collateral ligament as well as the posterior oblique ligament. The valgus force and the internal rotation are primarily resisted by their separate actions. Together, they have a complimentary relationship that contributes to the achievement of posteromedial stability and acts as secondary constraints to valgus, rotatory, anterior, and posterior stresses respectively. In addition, the medial patellofemoral ligament is the primary medial stabilizer of the patellofemoral joint. Its femoral attachment is located in close proximity to the femoral attachments of the medial knee stabilizers.

The major resistance against varus angulation comes from the multitude of ligamentous and tendinous components that make up the lateral compartment and posterolateral corner of the knee. Studies have shown that the Popliteus tendon (PT), the Popliteofibular ligament (PFL), and the Lateral Collateral Ligament (LCL) are the key contributors to the static and dynamic stability of the lateral and posterolateral corner of the knee. Instability of the lateral aspect of the knee, whether acute or chronic, is not as prevalent as medial knee instability. Injuries to the lateral structures of the knee frequently occur in conjunction with other knee injuries, such as tears to the cruciate ligaments or damage to the tissues responsible for medial knee stabilization. During a knee examination, it is easy to miss injuries to the posterolateral corner (PLC) structures of the knee, especially when there is a tear in the anterior cruciate ligament.

Due to their functional role, injuries affecting ligaments can lead to failure of the knee joint's normal functions thus impairing the physical functioning, and leading to interruption of the patient's daily activities both physically and economically.

There are several techniques described for the reconstruction of these ligaments. To successfully restore the natural anatomy and function of the joint, each of these procedures requires accurate identification of respective femoral, tibial, and fibular insertion sites. If reconstruction is performed by attaching the graft in a non-anatomic location, there are higher chances of graft failure and malfunction.

During intraoperative procedures, it might be challenging to pinpoint the exact attachment sites of the medial and lateral knee ligaments due to the presence of several layers of connective tissue and the fibrous reaction of the body. It becomes more difficult in case of chronic injuries due to tissue retraction and scarring, further obscuring the positions of these structures and their attachments, making it more difficult to reconstruct them correctly. Additionally, in revision knee surgeries, typical bony landmarks may be obscured or destroyed because of the presence of earlier reconstruction tunnels or hardware.

There are a lot of qualitative and quantitative gross anatomic descriptions of these medial and lateral knee ligamentous structures that can be found in the literature. On the other hand, there aren't many established and validated radiographic descriptions of the medial and lateral knee anatomy. When it comes to the surgical treatment of knee injuries, having a solid understanding of both the gross anatomy and the radiographic anatomy is essential.

Multiple studies have described various radiographic methods to identify the insertion sites of the ligaments intraoperatively, which are in turn based on the data of anatomic attachments provided by the cadaveric studies. On comparing the cadaveric studies, the insertion sites described varied in each study, this variation might be due to change in the demographic population cohort of the cadavers.

Hence in this study, we have tried to find the exact anatomical attachments of the ligaments in cadavers of Indian origin. Secondly, we have tried to assess the previously described radiological methods by implementing them on our cadavers and then comparing the attachment locations described by radiologically and anatomically known insertion sites described by cadaveric dissection.

REVIEW OF LITERATURE

Robert F. LaPrade et al.[1] conducted a study in 2003 on 10 fresh frozen cadaveric knees to quantitatively and qualitatively determine the anatomic attachments of posterolateral knee structures. They found that the fibular collateral ligament had an average femoral attachment slightly proximal (1.4 mm) and posterior (3.1 mm) to the lateral epicondyle. Distally, it attached 8.2 mm posterior to the anterior aspect of the fibular head. The popliteus tendon had a constant broad-based femoral attachment at the most proximal and anterior fifth of the popliteal sulcus. The popliteus tendon attachment on the femur was always anterior to the fibular collateral ligament. The average distance between the femoral attachments of the popliteus tendon and the fibular collateral ligament was 18.5 mm. The popliteofibular ligament had two divisions—anterior and posterior—in all cases. The average attachment of the posterior division was 1.6 mm distal to the posteromedial aspect of the tip of the fibular styloid process. The anterior division attached 2.8 mm distal to the anteromedial aspect of the tip of the fibular styloid process.

J.R Robinson et al.[2] 2004 studied the anatomy of posteromedial structures of the knee on 20 fresh frozen cadaveric knees. They divided the medial collateral ligament (MCL) complex into three parts, from anterior to posterior and into superficial and deep layers. They concluded that the main passive restraining structures of the posteromedial aspect of the knee were the superficial Medial collateral ligament (parallel, longitudinal fibers), the deep Medial collateral ligament, and the posteromedial capsule (PMC). The superficial and deep layers blend posteriorly. Although there are oblique fibers (capsular condensations) running posterodistally from the femur to the tibia, no discrete ligament was seen. In extension, the PMC appears to be an important functional unit in restraining tibial internal rotation and valgus.

A study was conducted by Pietrini SD et al.[3] in 2009 on 11 cadaveric knee specimens. They studied the positions of the lateral collateral ligament and popliteal tendon relative to other attachment sites and bony landmarks, which were labeled with radiopaque markers. They quantified these structures by using reference lines on anteroposterior and lateral radiographs. They found that in an anteroposterior view, the perpendicular distances of the popliteus tendon, and proximal fibular collateral ligament from a line intersecting the femoral condyles were 14.5 and 27.1mm, respectively. On the lateral view, the femoral attachments of the fibular collateral ligament, and popliteus tendon from the lateral epicondyle were 4.3 and 12.2 mm, respectively. In addition, they found that the lateral collateral ligament and popliteal tendon were located within the posteroinferior quadrant bound by the posterior femoral cortex extension reference line and another reference line perpendicular to it at the posterior margin of Blumensaat's line. And they concluded that both bony landmarks and superimposed reference lines on radiographs is an effective methods to measure the locations of the main posterolateral structure attachments because it allows not only for quantification of the attachment sites radiographically, but could also prove directly advantageous from a clinical standpoint.

A study was conducted by Wijdicks CA et al.[4] in 2009 on 11 fresh frozen cadaveric knees. Radiopaque markers were implanted into the femoral and tibial attachments of the superficial medial collateral ligament and the femoral attachments of the posterior oblique and medial patellofemoral ligaments. Both anteroposterior and lateral radiographs were obtained, and structures were assessed within quadrants formed by the intersection of reference lines projected on the lateral radiographs. Quantitative measurements were performed by three independent examiners. Intraobserver reproducibility and interobserver reliability were determined using intraclass correlation coefficients. They found that the overall intraclass correlation coefficients for intraobserver reproducibility and interobserver reliability were 0.996 and 0.994, respectively. On the anteroposterior radiographs, the attachment sites of the superficial medial collateral ligament, posterior oblique ligament, and medial patellofemoral ligament were 30.5 ± 2.4 mm, 34.8 ± 2.7 mm, and 42.3 ± 2.1 mm from the femoral joint line, respectively. On the lateral femoral radiographs, the attachment of the superficial medial collateral ligament was 6.0 ± 0.8 mm from the medial epicondyle and was located in the anterodistal quadrant. The attachment of the posterior oblique ligament was 7.7 ± 1.9 mm from the gastrocnemius tubercle and was located in the posterodistal quadrant. The attachment of the medial patellofemoral ligament was 8.9 ± 2.0 mm from the adductor tubercle and was located in the anteroproximal quadrant. On the lateral tibial radiographs, the proximal and distal tibial attachments of the superficial medial collateral ligament were 15.9 ± 5.2 and 66.1 ± 3.6 mm distal to the tibial inclination, respectively.

A study done by Lui F et al.[5] in 2010, this study measured the anatomy of the Medial collateral ligament complex by dissection of 10 cadaveric human knee specimens. The specimens were fixed in full extension, and this position was maintained during the dissection and morphometric measurements. The outlines of the insertion sites of the superficial MCL (sMCL) and deep MCL (dMCL) were digitized using a 3D digitizing system. They found that the insertion areas of the superficial MCL (sMCL) were 348.6 ± 42.8 mm^2 and 79.7 ± 17.6 mm^2 on the tibia and femur, respectively. The insertion areas of the deep MCL (dMCL) were 63.6 ± 13.4 mm^2 and 71.9 ± 14.8 mm^2 on the tibia and femur, respectively. The distances from the centroids of the tibial and femoral insertions of the sMCL to the tibial and femoral joint line were 62.4 ± 5.5 mm and 31.1 ± 4.6 mm, respectively. The distances from the centroids of dMCL in the tibial insertion and the femoral insertion to the tibial and femoral joint line were 6.5 ± 1.3 mm and 20.5 ± 4.2 mm, respectively. The distal portion of the dMCL (meniscotibial ligament - MTL) was approximately 1.7 times wider than the proximal portion of the dMCL (meniscofemoral ligament - MFL), whereas the MFL was approximately 3 times longer than the MTL.

A study conducted by Hartshorn T et al.[6] in 2013 to determine a reproducible radiographic landmark of Superficial medial collateral ligament, that will assist in correct femoral tunnel placement in its repair and reconstruction by performing dissection on 10 fresh frozen cadaveric knees. They found that the mean measurements showed the sMCL origin to be closely related to the intersection point of the Blumensaat line and a line drawn distally from the posterior femoral cortex on a true lateral radiograph. The sMCL origin was found at a mean point 1.6 ± 4.3 mm posterior and 4.9 ± 2.1 mm proximal to the intersection of a line paralleling the posterior femoral cortex and a line drawn perpendicular to the posterior femoral cortical line, where it intersects the Blumensaat line. In 5 of 10 specimens, the center of the sMCL origin fell precisely on the Blumensaat line. The remaining specimens had sMCL origins anterior to the Blumensaat line. The femoral origin of the sMCL was found in the proximal and posterior quadrants in 8 of 10 specimens.

A study conducted by Siago T et al.[7] in 2016 on 22 cadaveric knees described the insertions of the superficial medial collateral ligament (sMCL) and posterior oblique ligament (POL) and their related osseous landmarks and compared with 3-dimensional computed tomographic images. The femoral insertion of the POL was located 18.3 mm distal to the apex of the adductor tubercle (AT). The femoral insertion of the sMCL was located 21.1 mm distal to the AT and 9.2 mm anterior to the POL. The angle between the femoral axis and femoral insertion of the sMCL was 18.6 degrees, and that between the femoral axis and the POL insertion was 5.1 degrees. The anterior portions of the distal fibers of the POL were attached to the fascia cruris and semimembranosus tendon, whereas the posterior fibers were attached to the posteromedial side of the tibia directly. The tibial insertion of the POL was located just proximal and medial to the superior edge of the semimembranosus groove. The tibial insertion of the sMCL was attached firmly and widely to the tibial crest. The mean linear distances between the tibial insertion of the POL or sMCL and joint line were 5.8 and 49.6 mm, respectively.

A study conducted by K.K Athwal et al.[8] in 2020 on 22 fresh frozen cadaveric knees to define the bony attachments of the superficial MCL (sMCL), deep MCL (dMCL), and posterior oblique ligament (POL), plus the medial epicondyle (ME) relative to anatomical and radiographic bony landmarks by placing radio-opaque beads at femoral and tibial attachments of structures. They concluded that the femoral sMCL attachment enveloped the ME, centered 1 mm proximal to it, at 37 ± 2 mm (normalized at 53 ± 2%) posterior to the most-anterior condyle border. The femoral dMCL attachment was 6 mm (8%) distal and 5 mm (7%) posterior to the ME. The femoral POL attachment was 4 mm (5%) proximal and 11 mm (15%) posterior to the ME. The tibial sMCL attachment spread from 42 to 71 mm (81–137% of A-P plateau width) below the tibial plateau. The dMCL fanned out anterodistally to a wide tibial attachment 8 mm below the plateau and between 17 and 39 mm (33–76%) A-P. The POL is attached 5 mm below the plateau, posterior to the dMCL. The 95% CI intra-observer was ± 0.6 mm, inter-observer ± 1.3 mm for digitization. The inter-observer ICC for radiographs was 0.922.

A study by Kremen et al.[9] in 2020 on 29 human cadaveric knee specimens to compare previously described radiographic parameters for the localization of the lateral knee (LK) structures, including the popliteal tendon (Pop), anterolateral ligament (ALL), and lateral collateral ligament (LCL), to determine which method best estimates the femoral attachment of each LK structure. The femoral attachment for each structure was labeled with a radiopaque bead. LK radiographic images were obtained using fluoroscopy. Two radiographic approaches were used to identify each LK structure (Pop-A, Pop-B, LCL-A, LCL-B, ALL-A, and ALL-B) via previously published methods based on radiographic landmarks including the posterior femoral cortex and the Blumensaat line. The identification of radiographic landmarks was performed at 2 different time points by 2 different surgeons to determine the Pearson correlation between values, as well as interobserver and intraobserver reliability and reproducibility. They found that the LCL, the mean difference between the actual location and the estimated location via application of the LCL-B method (5.0 2.4 mm) was significantly less than that estimated using the LCL-A method (8.2 3.3 mm, P < .0001). Likewise, the Pop-B (5.7 2.0 mm) and ALL-B (9.3 4.5 mm) methods were shown to have smaller differences between the actual and estimated femoral attachment sites of the Pop insertion and ALL insertion, respectively (P < .0001). Methods for estimating the ALL femoral origin were the worst among the LK structures analyzed, with 90% of estimated values greater than 5 mm from the anatomic origin. Interobserver and intraobserver intraclass correlation coefficients were 0.785 or higher. They concluded that previously described radiographic methods for localization of the femoral attachment sites of the LK structures resulted in estimated locations that were significantly different from the locations of the radiographic beads placed at the anatomic femoral attachment sites of these structures. Therefore, radiographic methods used to localize the femoral attachments of the LK structures may not be reliable.

A study was conducted by Schottle P. B. et al.[10] in 2007 on eight fresh-frozen human cadaveric knees to determine the radiographic landmarks for control of postoperative and intraoperative femoral medial patellofemoral ligament insertion. After identification of the femoral medial patellofemoral ligament insertion site, the insertion center was marked with a lead ball of 2 mm diameter. Serial lateral radiographs were taken, and posterior-anterior, as well as proximal-distal positions, were evaluated. They found that six of 8 insertion points were anterior to a line representing an extension of the posterior cortex, 1 point was touching this line, and 1 point was posterior to it. All points were situated distal to the posterior origin of the medial femoral condyle and proximal to the most posterior point of the Blumensaat line. A reproducible anatomical and radiographic point, 1.3 mm anterior to the posterior cortex extension and 2.5 mm distal to the posterior origin of the medial femoral condyle, just proximal to the level of the posterior point of the Blumensaat line on a lateral view with the posterior condylar margin overlapped, determined the radiographic landmarks for the mean femoral MPFL center. These landmarks not only can be used for postoperative control but also to verify the femoral insertion for MPFL reconstruction intraoperatively.

A study conducted by Ziegler C. G. et al.[11] in 2015 on ten fresh-frozen human cadaveric knees to quantify the magnitude of MPFL femoral tunnel malposition that occurs on true lateral and aberrant lateral knee radiographs when using a previously reported radiographic technique for MPFL femoral tunnel localization. After dissection to expose the MPFL femoral insertion and surrounding medial knee anatomy. True lateral and aberrant lateral knee radiographs at 2.5 degrees, 5 degrees, and 10 degrees off-axis were obtained with a standard mini C-arm in 4 orientations: anterior to posterior, posterior to anterior, caudal, and cephalad. A previously reported radiographic method for MPFL femoral localization was performed on all radiographs and compared in reference to the anatomic MPFL attachment center. They found a mean distance of 4.1 mm from the anatomic MPFL attachment on a true lateral knee radiograph. The distance between the anatomic MPFL attachment center and the radiographic point significantly increased on aberrant lateral knee radiographs with as little as 5 degrees of rotational error in 3 of 4 orientations of rotation when a standard mini C-arm was used. This corresponded to a malposition of 7.5, 9.2, and 8.1 mm on 5 degrees -aberrant radiographs in the anterior-posterior, posterior-anterior, and cephalad orientations, respectively ($P < .005$). In the same 3 orientations of rotation, MPFL tunnel malposition on the femur exceeded 5 mm on 2.5 degrees aberrant radiographs. They found that in inaccurate tunnel localization on a true lateral radiograph, and this inaccuracy is perpetuated with aberrant radiography. Aberrant lateral knee imaging of as little as 5 degrees off-axis from true lateral has a significant effect on the placement of a commonly used radiographic point relative to the anatomic MPFL femoral attachment center and results in nonanatomic MPFL tunnel placement.

A study conducted by Pfeiffer T.R. [12] in 2018 on thirteen fresh-frozen human cadaveric knees to determine whether a fluoroscopic technique can be used to improve the accuracy of the determination of the femoral origin of the lateral collateral ligament

(LCL). A 1 cm incision was given over lateral epicondyle and the LCL origin was determined first by palpation and then with a previously described fluoroscopic method. Both points for the LCL origin were marked with 2-mm Kirschner wires. The distances between the center of the anatomic LCL origin and the LCL origin points determined by palpation and fluoroscopic imaging were calculated. An independent t-test was used to compare the distances between the anatomic LCL origin center and the determined LCL origin points. They found that the LCL origin points determined by fluoroscopic imaging were significantly (P= .005) closer to the anatomic center of the LCL origin point than the ones determined by palpation (3.2 mm ± 1.6 mm vs 5.0 mm ± 1.6 mm, respectively). A total of 92.7% fluoroscopically determined LCL origin points were within a 5 mm radius surrounding the anatomic LCL origin point. In contrast, only 53.8% LCL origin points determined by palpation were within a 5 mm radius surrounding the anatomic LCL origin point.

A study conducted by Fok A. W. M. et al.[13] in 2015 on ten fresh-frozen human cadaveric knees determined that the femoral insertion of the popliteus tendon could be more precisely determined by the Blumensaat line than by the extension line of the posterior cortex, by using standardized radiographic techniques. After identification of the femoral insertion site of the popliteus tendon by cadaveric dissection, the insertion’s centre was indicated with a radiographic marker. True lateral radiographs of the distal femur were taken, and the digital radiographic images were analysed by 2 independent observers. They found that the femoral insertion site of the popliteus tendon was found to be a mean 47.5% ± 5.2% across the width of the femoral condyle, 60.7% ± 7.8% along the perpendicular bisector of the Blumensaat line, 0.3 ± 1.7 mm posterior to the extension line of the posterior femoral cortex, and 20.5 ± 3.8 mm distal to the perpendicular line at the Blumensaat point. The variance from the mean point by using the Blumensaat line as a reference was significantly smaller than the extension line of the posterior cortex (mean, 2.6 vs. 3.6 mm; P = .044).

A study was done by Kamath G. V. et al.[14] in 2016 on eight fresh-frozen human cadaveric knees to determine the intraoperative fluoroscopic imaging can be used as an adjunctive tool for femoral tunnel placement during the posterolateral corner and LCL reconstruction by using standardized radiographic imaging. They have done cadaveric dissection to identify LCL origin and followed by, a radiographic marker inserted at its center. True lateral radiographs of the distal femur (posterior condyles overlapping) were taken. Digital radiographic images were obtained and analyzed. They found that the Blumensaat line was found to be closely associated with the LCL origin on lateral radiographic imaging. On average, the LCL ligament was found to be 58% (64.7%) across the condyle width and 2.3 mm (±2.3 mm) distal to the Blumensaat line. In all specimens, the anatomical LCL origin was found to have less than 5 mm variance from the mean.

A study was conducted by Balcarek p. et al.[15] in 2015 on six fresh frozen human cadaveric knees to evaluate the sensitivity of femoral tunnel placement of MPFL, using lateral fluoroscopic guidance to minor degrees of deviation from the true-lateral view using established radiographic techniques. The MPFL femoral insertion point was identified by established radiographic techniques based on cadaveric dissection and followed by 6 mm metal marker was placed in its center. Radiographic landmarks were also applied with the femur positioned in 2.5 degrees and 5 degrees of internal and external rotation, respectively, and with the femur in 2.5 degrees and 5 degrees of hip abduction and adduction, respectively. The distance between the center of the 6-mm eyelet to the center of the native femoral MPFL insertion, as established in the true-lateral view, was measured and determined as the degree of shift in each position. They found that in the position of Hip adduction, abduction, and internal and external rotations of 2.5 degrees resulted in a shift from the native femoral MPFL insertion point to a more distal (adduction), proximal (abduction), anterior (internal rotation), and posterior location (external rotation) of 2.7 ± 0.7, 2.0 ± 0.7, 2.7 ± 1.1, and 3.0 ± 1.3 mm, respectively ($P<0.05$). Malpositioning increased to a distance of 5.0 ± 0.7 mm distally, 3.6 ± 1.0 mm proximally, 5.2 ± 0.8 mm anteriorly, and 6.2 ± 0.6 mm posteriorly to the native insertion point when the attachment was marked with 5 degrees of divergence from the true-lateral view ($P<0.05$).

A study was conducted by Redfren J. et al.[16] in 2010 to determine whether the radiographic landmarks can be used to accurately determine the femoral insertion of the medial patellofemoral ligament in a percutaneous fluoroscopically guided surgical technique by doing dissection on eight fresh-frozen human cadaveric knees. The knees were dissected, and the true anatomical medial patellofemoral ligament femoral insertion was identified. Radiographic markers were placed on the estimated and anatomical medial patellofemoral ligament, and a repeat lateral radiograph was performed. Using imaging software, the distance between the true anatomical insertion and the fluoroscopically determined insertions was calculated. They found that all 8 points determined by fluoroscopically guided pin placement averaged less than 4 mm from the anatomical insertion. The radiographic landmark method consistently placed the origin on average 2.5 mm anterior and 0.6 mm distal to the anatomical insertion.

A study conducted by Kruckeberg B. M. et al.[17] in 2017 on ten fresh-frozen human cadaveric knees to determine a qualitative and quantitative anatomic and radiographic evaluation of the medial patellofemoral ligament (MPFL), medial patellotibial ligament (MPTL), medial patellomeniscal ligament (MPML), and medial quadriceps tendon femoral ligament (MQTFL) attachment sites, with attention to their relationship to pertinent osseous and soft tissue landmarks. The cadaveric were dissected, and the MPFL, MPTL, MPML, and MQTFL were identified. A coordinate measuring device quantified the attachment areas of each structure and its relationship to pertinent bony landmarks. Radiographic analysis was performed through ligament attachment sites and relevant anatomic structures to assess their locations relative to pertinent bony landmarks. They found that the four separate medial patellar ligaments were identified in all specimens. The center of the MPFL attachments was 14.3 mm proximal and 2.1 mm posterior to the medial epicondyle and 8.3 mm distal and 2.7 mm anterior to the adductor tubercle on the femur and 8.9 mm distal and 19.9 mm medial to the superior pole on the patella. The MQTFL had a mean insertion length of 29.3 mm on the medial aspect of the distal quadriceps tendon. The MPTL and MPML shared a common patellar insertion and were 9.1 mm proximal and 15.4 mm medial to the inferior pole. The MPTL attachment inserted on a newly identified bony ridge, which was located 5.0 mm distal to the joint line. The orientation angles of the MPTL and MPML with respect to the patellar tendon were 8.3 degrees and 22.7 degrees, respectively.

A study done by Placella G. et al.[18] in 2014 to investigate the shape and the attachments of the medial patellofemoral ligament (MPFL) in cadaver specimens to determine an anatomical basis for the best MPFL reconstruction by doing dissection over twenty fresh-frozen human cadaveric knees. They found that the distal fibers of MPFL were interdigitated with the deep layer of the medial retinaculum. All isolated ligaments had a sail-like shape with the patellar side bigger than the femoral side. The femoral insertion, distinct from the medial epicondyle and adductor tubercle, was located at 9.5 mm (range 4–22) distal and anterior with respect to the adductor tubercle and proximal and posterior to the epicondyle. The medial third of the thickness of the patella was involved in the insertion. The proximal third of the patella is always involved in the MPFL attachment; in 45 % of the cases, it was extended to the medial third, and in one case, an extension at the distal third was found. Additionally, in 35 % (7 cases), it extended to the quadriceps tendon, and it was inconstantly attached at the vastus medialis obliques (VMO) tendon and at the vastus intermedius (VI) tendon in an aponeurotic structure.

A study was conducted by Steensen R. N. [19] in 2004 on eleven fresh frozen cadaveric human knees to define the anatomy and isometry of the medial patellofemoral ligament. They have dissected the medial patellofemoral ligament in 11 cadaveric knees and recorded its anatomic relationships. They evaluated the isometry of the medial patellofemoral ligament by obtaining measurements between various anatomic pairings at certain fixed knee flexion angles. They found that the in all 11 knees, the MPFL attached directly to the entire length of the anterior aspect of the medial epicondyle and during knee flexion from 0° to 90°, the portion of the medial patellofemoral ligament from the inferior patellar attachment to the superior femoral attachment was nearly isometric, demonstrating an average change in length of only 1.1 mm. Statistical analysis showed the superior femoral attachment to be most significant in determining isometric behavior.

A study was conducted by Philippot R. et al.[20] in 2009 to perform a detailed anatomical analysis of the medial patellofemoral ligament (MPFL), especially its femoral attachment, its relationships with the vastus medialis obliquus (VMO) and the medial collateral ligament, with the objective of improving its surgical reconstruction based on twenty-three fresh-frozen human cadaveric knees. They found that the MPFL was always observed; its length was 57.7 ± 5.8 mm, and the junction between the VMO and the MPFL always present measured 25.7 ± 6.0 mm. When it comes to MPFL reconstruction, the key point is its positioning in the femoral insertion because it is this insertion that will restore isometry. Anatomically, it was positioned 10 mm behind the medial epicondyle and 10 mm distal to the adductor tubercle.

A study conducted by Panagiotopoulos E. et al.[21] 2004 on eight human cadaveric knees to describe the detailed anatomy of the static medial patellar stabilizers and further determine the role of each of them in preventing lateral patellar dislocation. They found that the MPFL length varies from 45–50 mm, and its width is from 10–20 mm at its origin (medial femoral epicondyle) to 20–30 mm at its insertion to the patella. The ''meshing'' of the MPFL fibers to the fibers of the vastus medialis obliquus (VMO) close to its patellar insertion was the most interesting and significant finding. The contribution of MPFL to medial stability was more than 50%. Of the remaining ligaments, MPML contributes 24% and the MPTL and MR contribute only 13% respectively. The MPFL is the most robust medial static patellar stabilizer. Its contribution to patellar stability against lateral dislocation is far more than 50%, since its meshing with the VMO, shortens its fibers which thus pulls the patella to the medial part of the femoral groove and keeps it in the trochlea during the initial 20 degrees – 30 degrees of flexion.

AIM AND OBJECTIVES

Aim:

Assessment of comparing between anatomical attachments (marked by cadaveric dissection) with the radiographically marked location of Medial and Lateral knee ligaments by described methods in the literature for Indian knees

Objectives:

1. To evaluate the anatomical attachments of medial and lateral knee ligaments in Indian cadaveric knees via dissection.
2. Comparison of anatomical attachments of ligaments of the knee with radiographic locations obtained by various published methods.
3. To assess the Inter-observer and Intra-observer correlation of radiographic methods for assessing the ligament attachments.

STATISTICAL ANALYSIS

Kremen *et. al. [9]* have found a correlation of 0.785. Using this for calculation, we estimate a sample size of 18 knees at 90% power and 99% confidence interval and 10% contingency.

Statistical Analysis Plan:

Continuous data will be described using mean and standard deviation and compared using the independent sample t test. Pearson's Correlation coefficient will be used to determine the correlation between variables. A p-value of less than 0.05 will be considered as significant.

Sampling Size:

Calculation steps:

The standard normal deviate for $\alpha = Z_\alpha = 2.5758$

The standard normal deviate for $\beta = Z_\beta = 1.2816$

$C = 0.5 * \ln[(1+r)/(1-r)] = 1.0583$

Total sample size = $N = [(Z_\alpha+Z_\beta)/C]2 + 3 = 18$

METHODOLOGY

Study design: Observational study

Sampling frame:

18 knees (9 cadavers) meeting the inclusion criterion from the time of approval of the thesis to 18 months.

Inclusion criteria:

Formalin treated cadaveric knees without any prior anatomical abnormalities.

Exclusion criteria:

1. Age <18 years.
2. Cadavers with any prior fractures.
3. Cadavers with any prior ligament injuries and knee surgeries.

Research question:

Whether the radiographic estimation of Medial and Lateral ligament attachments correlate with actual anatomical attachments in the Indian knees.

Research hypothesis:

Null hypothesis: The radiographic estimation of Medial and Lateral ligament attachments adequately correlates with actual anatomical attachments in Indian knees.

Alternative hypothesis: The radiographic estimation of Medial and Lateral ligament attachments poorly correlate with actual anatomical attachments in Indian knees.

In the cadaveric dissection lab of the Department of Anatomy, AIIMS Jodhpur, eighteen formalin-treated paired cadaveric knees with mean age of 79 ± 11.16 years (Range, 65-100 years) were dissected. In terms of gross deformity, we examined each specimen to confirm that there were no preexisting scars at the knee or indications of lateral condyle hypoplasia, as well as the existence of any implanted hardware, such as knee arthroplasty components or metal plates and screws from earlier surgical operations and this was confirmed by inspection during the dissection process**.**

Medial side dissection:

The dissection began with a longitudinal midline skin incision of the knee measuring 20 cm proximal to the proximal pole of the patella to 10 cm distal to the tibial tuberosity. After that, the skin was removed as medial and lateral flaps. An incision was made in the subcutaneous tissue that was located on the medial side of the knee. The tendons and muscles of the sartorius, gracilis, and semitendinosus were dissected and freed from their attachments to the tibia. Further in-depth dissection was carried out in order to separate the medial epicondyle as well as the osseous attachments of the superficial medial collateral ligament, the posterior oblique ligament, and the medial patellofemoral ligament. Soft tissues were removed from the femoral attachment of the superficial medial collateral ligament, the tibial attachment of the superficial medial collateral ligament, the femoral attachment of the posterior oblique ligament, and the femoral attachment of the medial collateral ligament.

A horizontal incision was made along the medial joint line and at the midsubstance of ligaments after identifying the ligaments of interest on both the femur and tibia. The sMCL and POL were dissected on the femur from distal to proximal until the footprints were recognized. MPFL was carefully dissected in layers of the joint capsule until the MPFL fibers were recognized. Palpating the medial condyle revealed the medial epicondyle, a highly convex elevation on the medial end of the distal femur. Similarly, the sMCL ligament was dissected from proximal to distal on the medial aspect of the tibia until its footprint was found.

After the footprints of the ligaments were located on the femur and the tibia, the footprints of the ligaments and the bone landmarks were highlighted in the center with colour markers. A black colour was used to highlight the medial epicondyle, red was used to highlight the sMCL, blue was used to highlight the POL, and green was used to highlight the MPFL. A metal marker was inserted into the bony landmark and ligament footprints. The medial epicondyle footprint had an iron nail with a head measuring 3 mm in diameter pushed into the center of it. The femoral and tibial ligament footprints, each had an iron nail with a brass bead measuring 4.5 mm in diameter hammered with bone into the center of their respective footprints.

Figure 1 (a,b) shows the medial knee ligaments after medial side cadaveric dissection.

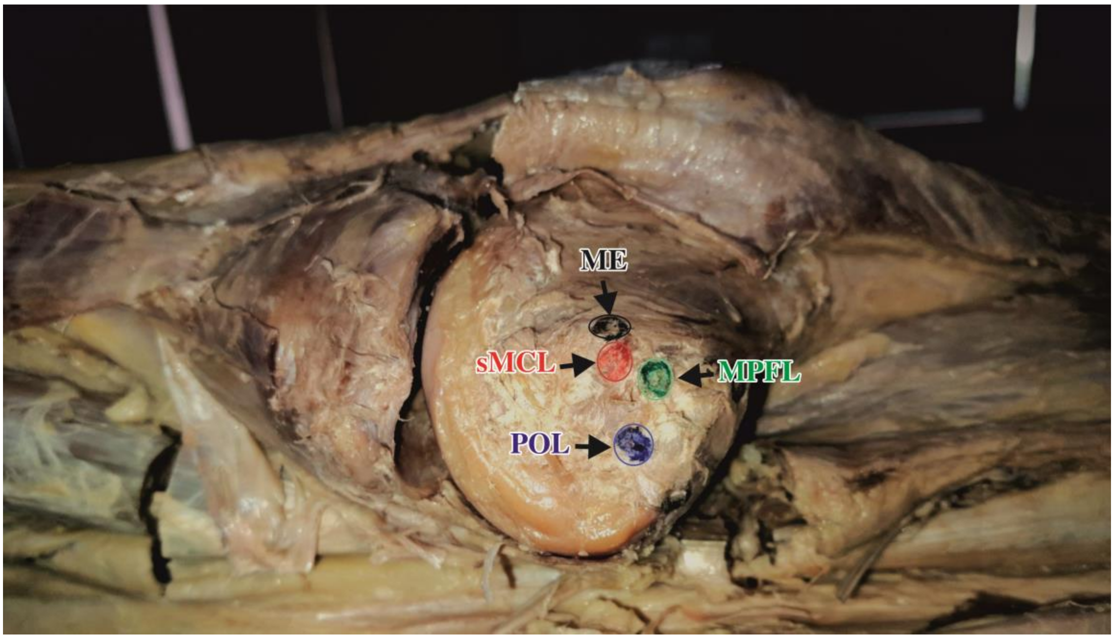


Figure 2 shows the marking of medial knee ligament footprints and ME with different colour markers.

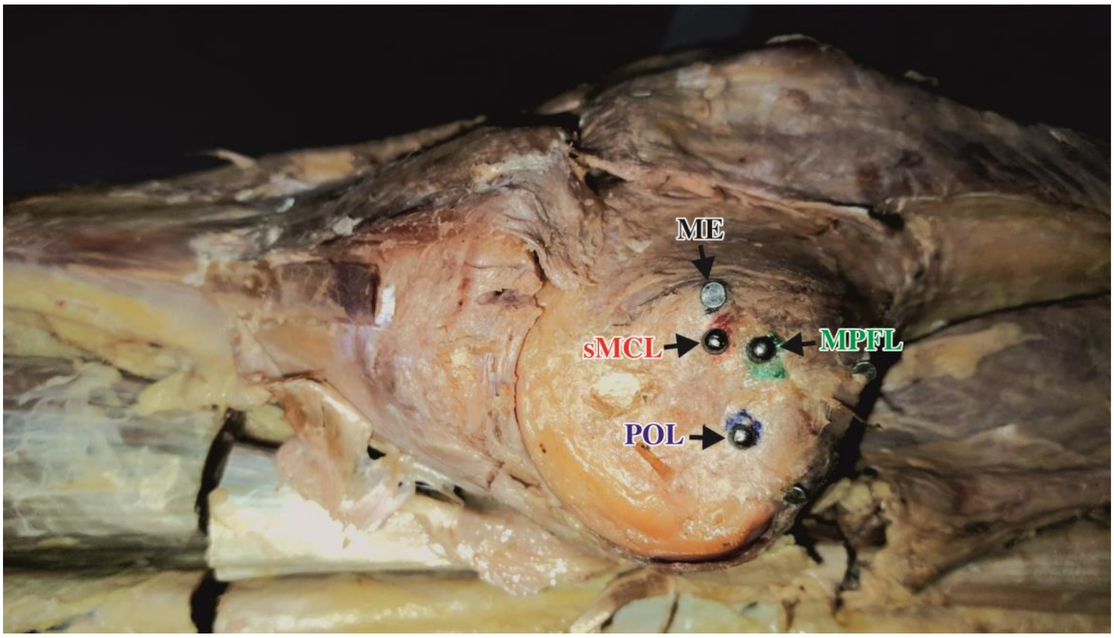


Figure 3 shows the metal beads and nails hammered into the medial knee ligament footprints and ME.

Lateral side dissection:

On the lateral aspect of the knee, the skin and the subcutaneous tissues were excised to reveal the superficial layer of the iliotibial band as well as the insertion of the biceps femoris muscle. In order to identify the structures that are located more laterally, facial incisions were made, followed by a horizontal incision that was made across the biceps bursa. Blunt dissection was utilized to locate the space that exists between the lateral gastrocnemius and soleus muscles to get visual access to the structures that are located further toward the posterolateral aspect of the knee. The dissection was completed by incising the popliteus muscle belly distal to the medial attachment of the popliteofibular ligament and retracting it proximally to find the popliteus musculotendinous ligament, the tibial attachment of the Lateral collateral ligament, and the femoral attachment of the Popliteus tendon that was removed.

After identifying the ligaments of interest on both the femur and fibula, a horizontal incision was made along the lateral joint line and at the midsubstance of the ligaments. The LCL and PT were dissected on the femur from distal to proximal until the footprints were identified. Palpating the lateral condyle showed the lateral epicondyle, a strongly convex elevation on the lateral end of the distal femur. Similarly, the LCL ligament was dissected from proximal to distal on the lateral part of the knee until its footprint was identified on the fibular head.

After the femoral and fibular ligament footprints were located, the footprints and bone landmarks were marked in the center with color markers. A black marker was used to indicate the lateral epicondyle, a red marker was used to indicate the LCL, and a blue marker was used to indicate the PT. And later metal markers were inserted into a bony landmark and ligament footprints. An iron nail with a head measuring 3 millimeters in diameter was placed into the footprint of the lateral epicondyle, and an iron nail with a brass bead measuring 4.5 millimeters in diameter was inserted into the footprints of the femur and the fibula.

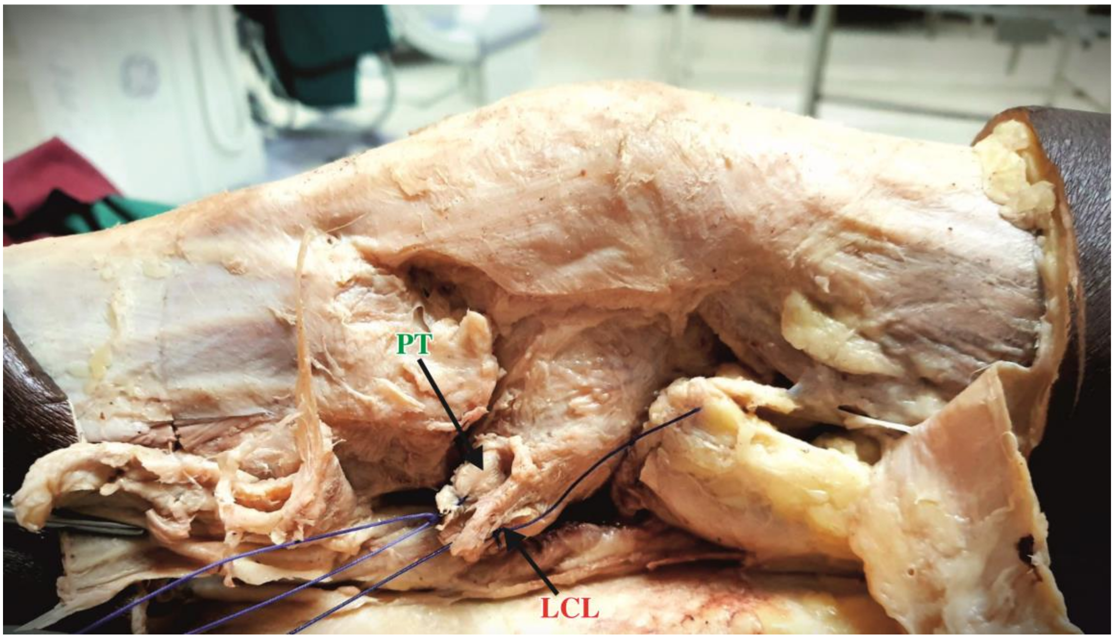
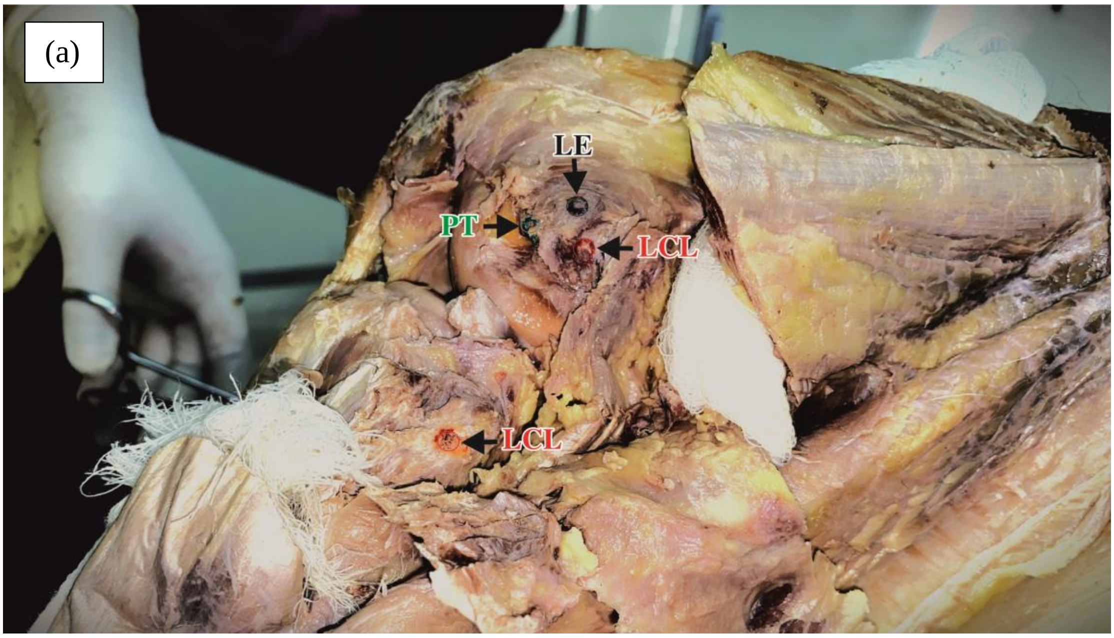


Figure 4 shows the lateral knee ligaments after lateral side cadaveric dissection.



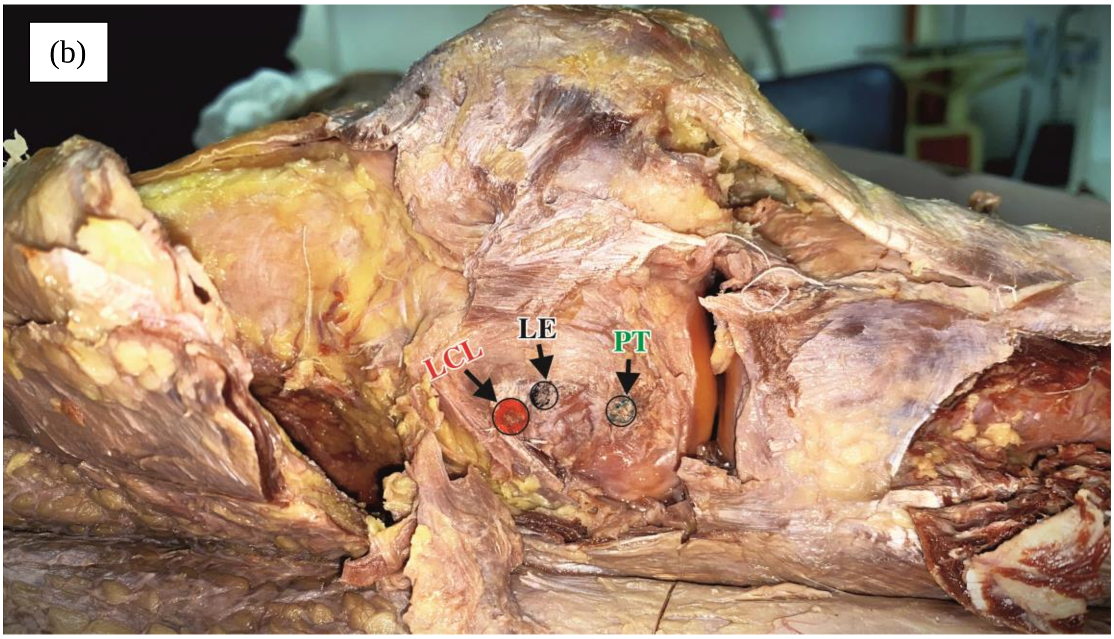


Figure 5 (a,b) shows the marking of lateral knee ligament footprints and LE with different colour markers.

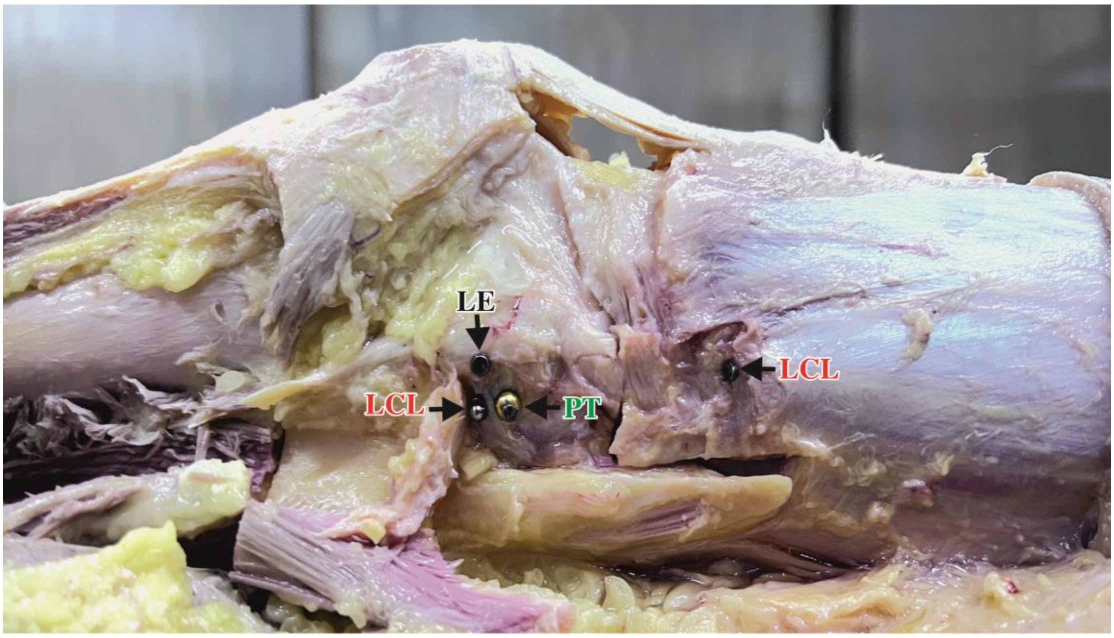


Figure 6 shows the metal beads and nails hammered into the lateral knee ligament footprints and LE.

Image collection:

A fluoroscopy C-arm was used to capture images of each specimen in true anteroposterior and true lateral views. True Anteroposterior views are obtained with the anterior and posterior margins of the medial tibial plateau closely superimposed and the tibial eminences positioned at the center of the femoral intercondylar notch. True lateral radiographs are obtained by ensuring that the posterior aspects of the medial and lateral femoral condyles overlap. We used the length of the nail as the standard calibration in the AP radiograph and the diameter of a metal/brass bead in the lateral radiograph to compensate for the magnification discrepancies caused by probable fluctuation in distances between the specimens and the x-ray source.

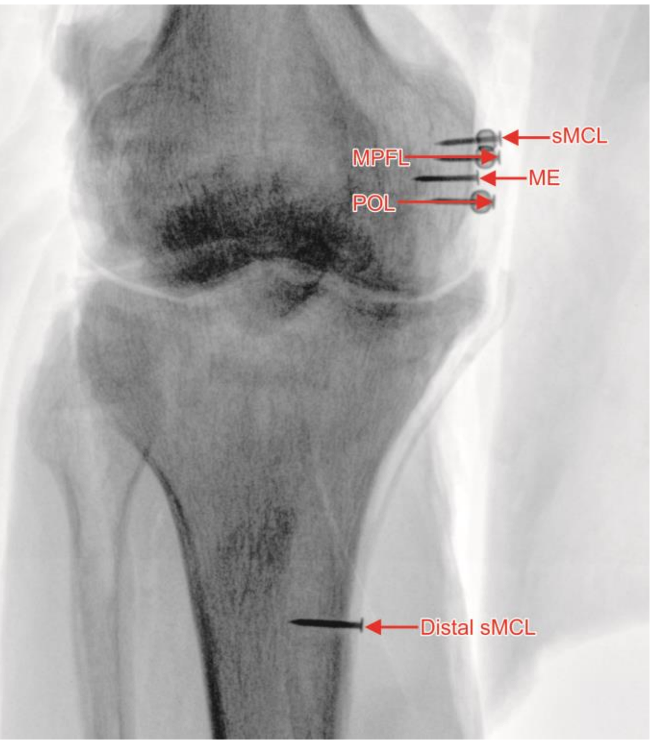


Figure 7 shows the fluoroscopic image in the anteroposterior view with medial knee ligament footprints and ME with metal beads and nails.

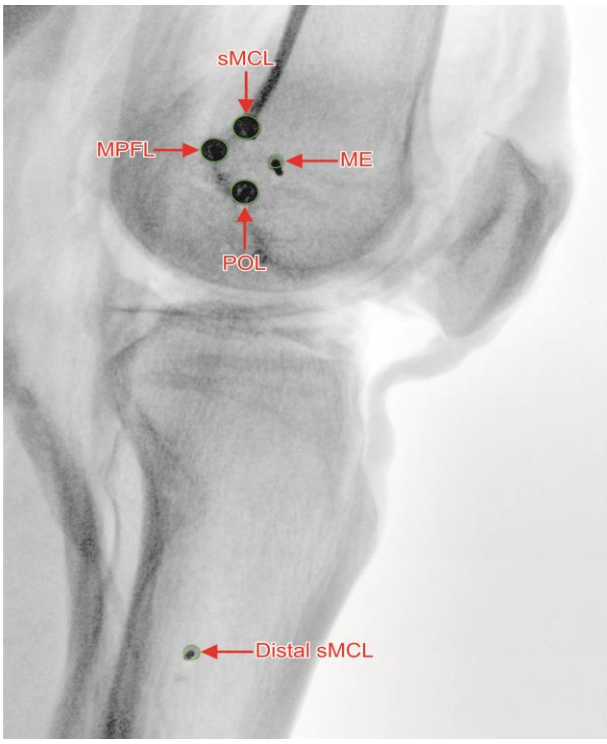


Figure 8 shows the fluoroscopic image in the lateral view with medial knee ligament footprints and ME with metal beads and nails.

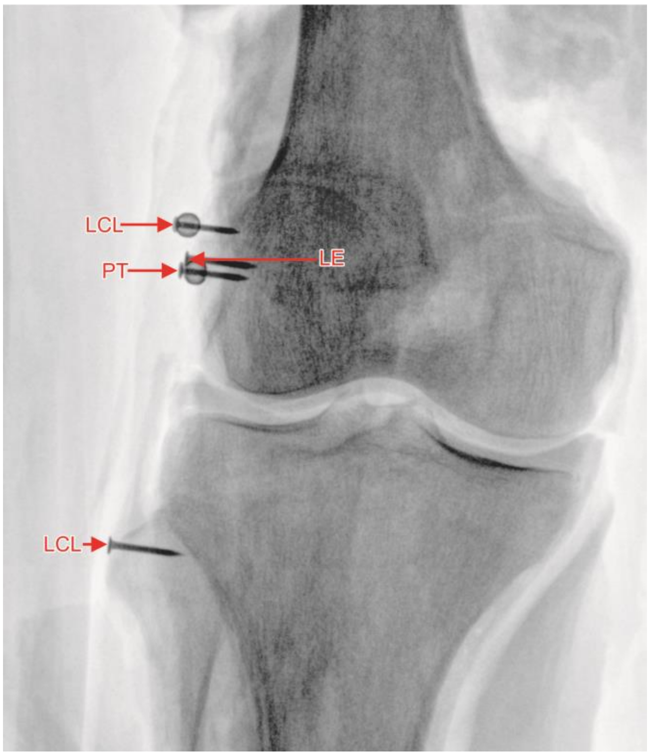


Figure 9 shows the fluoroscopic image in the anteroposterior view with lateral knee ligament footprints and LE with metal beads and nails.

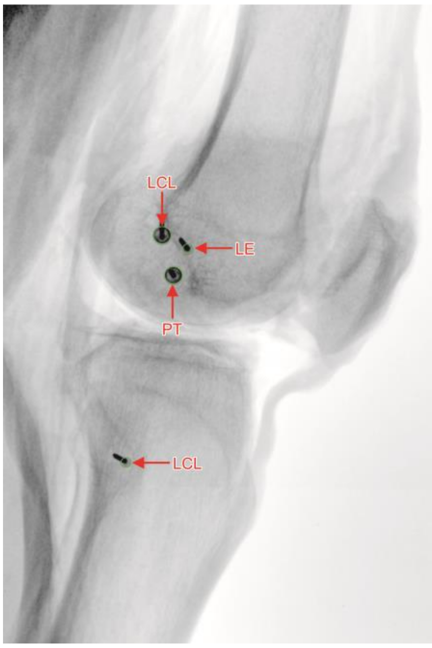


Figure 10 shows the fluoroscopic image in the lateral view with lateral knee ligament footprints and LE with metal beads and nails.

Measurements:

All of the footprints of the medial and lateral ligaments of the knee that were of interest were measured using RADIANT DICOM software (Medixant, version 2022.1.1 64-bit) to obtain anatomical and radiographic measurements from each fluoroscopic image.

On the lateral images of the femur, the anatomical measurements were taken from the bony landmark to ligaments of interest (sMCL, POL, MPFL, LCL & PT) in the X and Y coordinate system; Y-Axis was made along the shafts of the femur and X-axis was a perpendicular line to Y-axis in the lateral image with an intersecting point of both axes over the bony landmark (0,0), to determine the distance between the imprints of the sMCL, POL, MPFL and ME medially and, LCL, PT and LE laterally. Similarly, the linear distances between the ligament imprints and bony landmarks were measured.

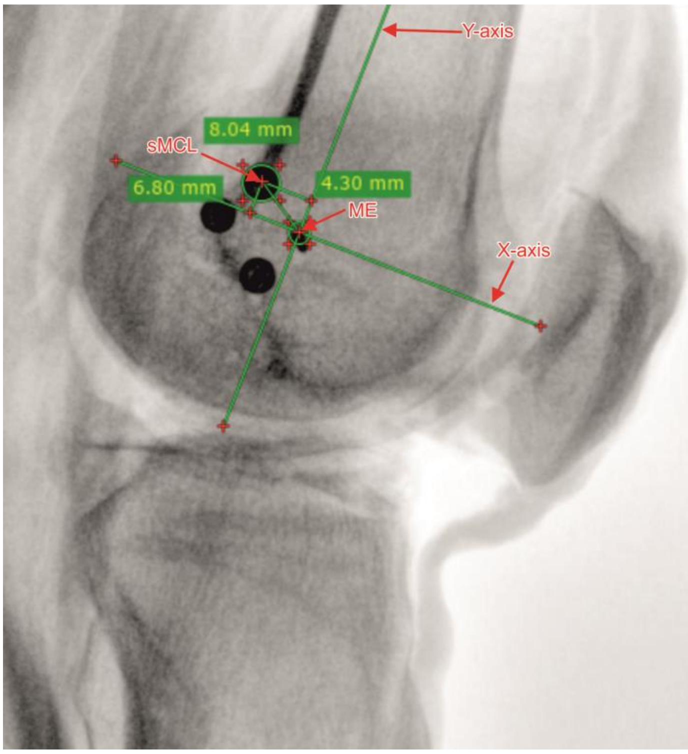


Figure 11 shows the anatomical measurements of the Superficial medial collateral ligament (sMCL) from ME.

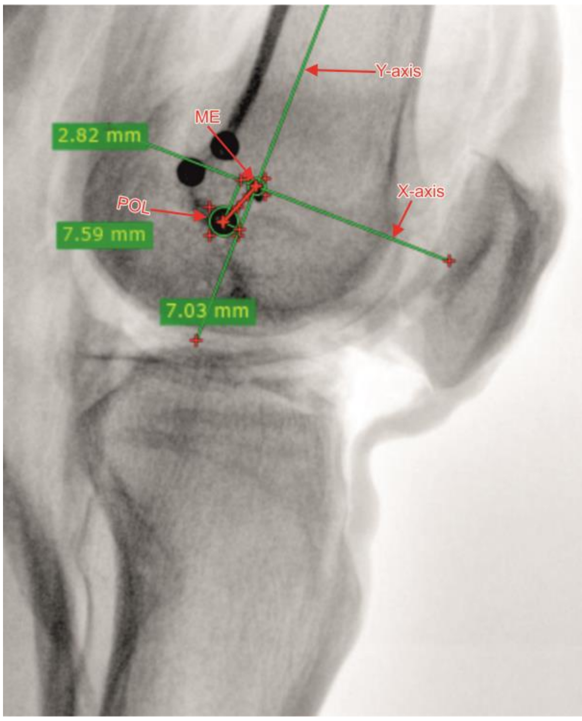


Figure 12 shows the anatomical measurements of the Posterior oblique ligament (POL) from ME.

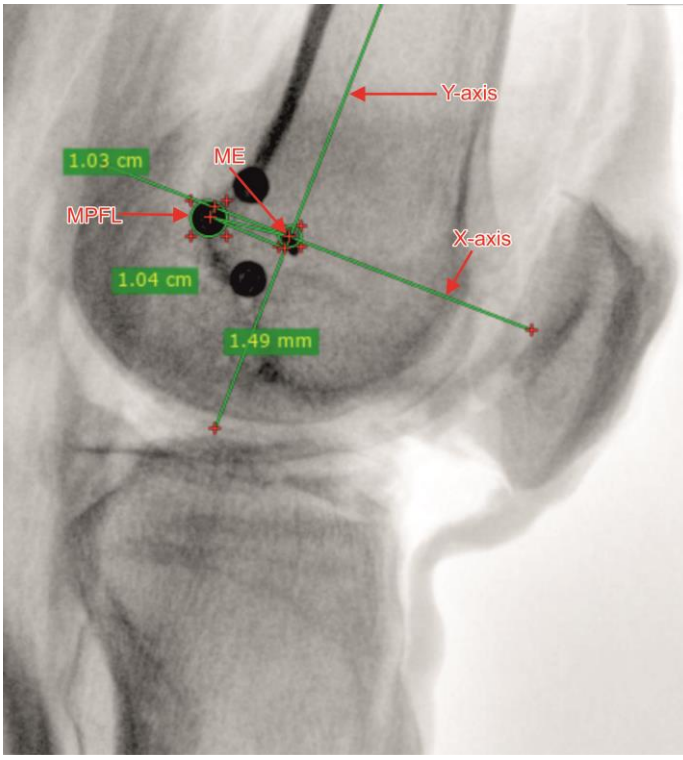


Figure 13 shows the anatomical measurements of the Medial patellofemoral ligament (MPFL) from ME.

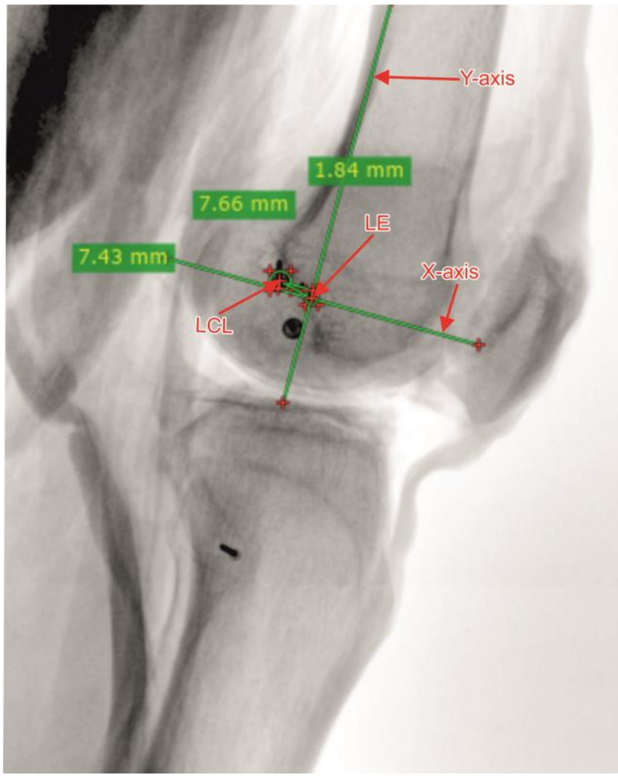


Figure 14 shows the anatomical measurements of the Lateral collateral ligament (LCL) from LE.

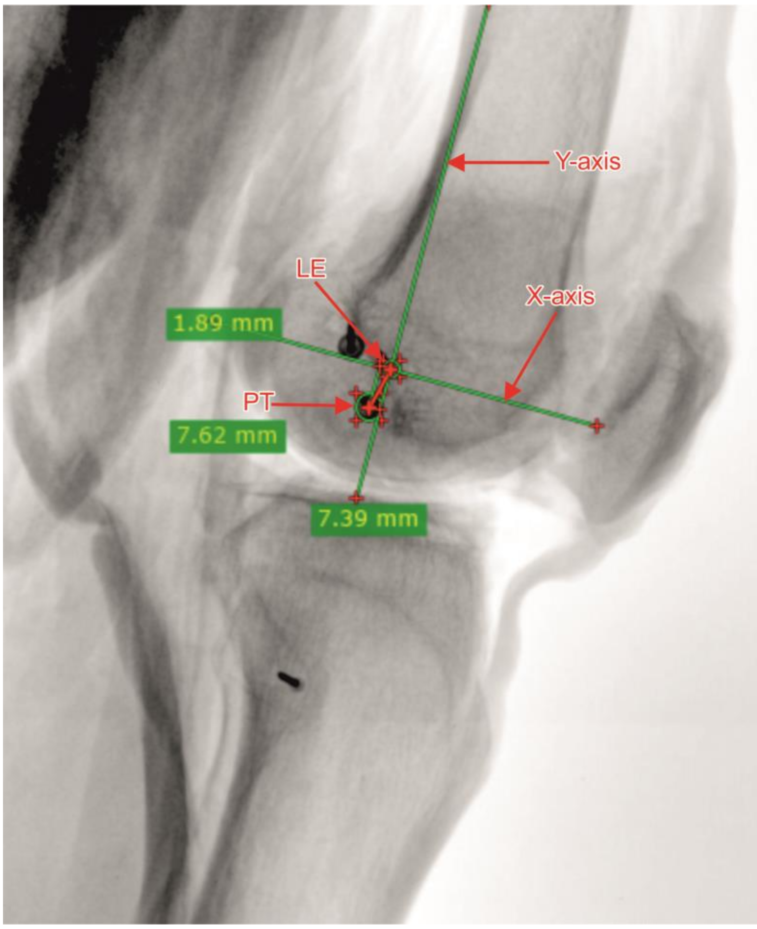


Figure 15 shows the anatomical measurements of the Popliteus tendon (PT) from LE.

For radiographic measurements of the ligament attachment on the femur, tibia, and fibula, techniques that have been used commonly, by some different authors were used.

The radiographic landmarks for medial knee ligaments were marked according to the methods described by the following authors.

	STUDIES	RADIOLOGICAL TECHNIQUE USED
sMCL	KK Athwal et al.[8]	• Only in lateral view, based on the schottles technique [10] (Line1[Y-axis]; posterior femoral cortex extension line, Line2[X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) Only quantitative
	Hartshorn et al.[6]	• Qualitative, only in lateral view, (in quadrants, formed by line 1 [Y-axis]; posterior femoral cortex extension line, line 2 [X-axis]; line perpendicular to line 1, where it intersects the blumensaat line) • Quantitative, only in lateral view, the radiological landmark is an intersection point of line1 & line 2
	Wijdicks et al.[4]	• Qualitative, only in lateral view, (in quadrants, formed by Line1 [Y-axis]; posterior femoral cortex extension line, Line2 [X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) • Quantitative, from the bony landmark (ME) and reference lines on femur and tibia in both AP and Lateral view x-rays

Table 1: Radiological techniques used for superficial medial collateral ligament (sMCL).

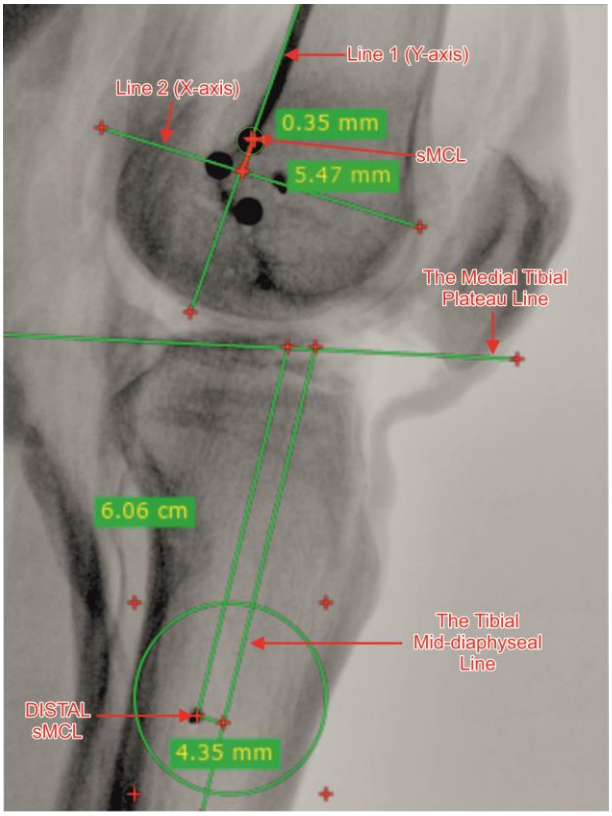


Figure 16 shows the radiological measurements of sMCL by Wijdicks et al.[4] technique in lateral view.

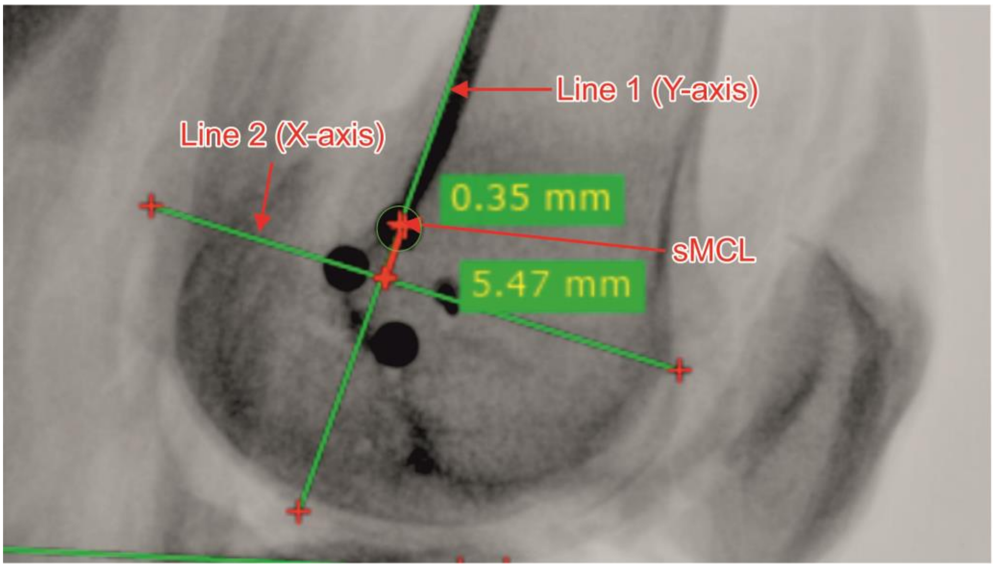


Figure 17 shows the radiological measurements of sMCL by KK Athwal et al.[8] technique in lateral view.

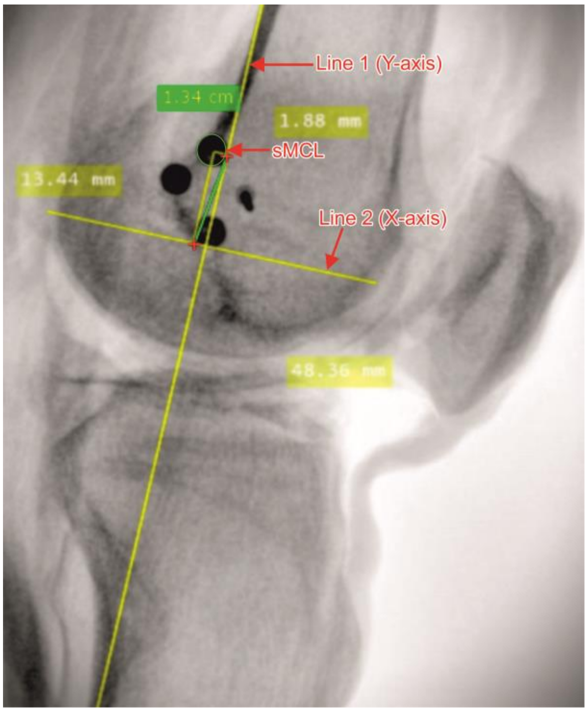


Figure 18 shows the radiological measurements of sMCL by Hartshorn et al.[6] technique in lateral view.

	STUDIES	RADIOLOGICAL TECHNIQUE USED
POL	KK Athwal et. al [8]	• Only in lateral view, based on the schottles technique (Line1[Y-axis]; posterior femoral cortex extension line, Line2[X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) Only quantitative
	Wijdicks et al. [4]	• Qualitative, only in lateral view, (in quadrants, formed by Line1 [Y-axis]; posterior femoral cortex extension line, Line2 [X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) • Quantitative, from the bony landmark (ME) and reference lines on femur and tibia in both AP and Lateral view x-rays

Table 2: Radiological techniques used for posterior oblique ligament (POL).

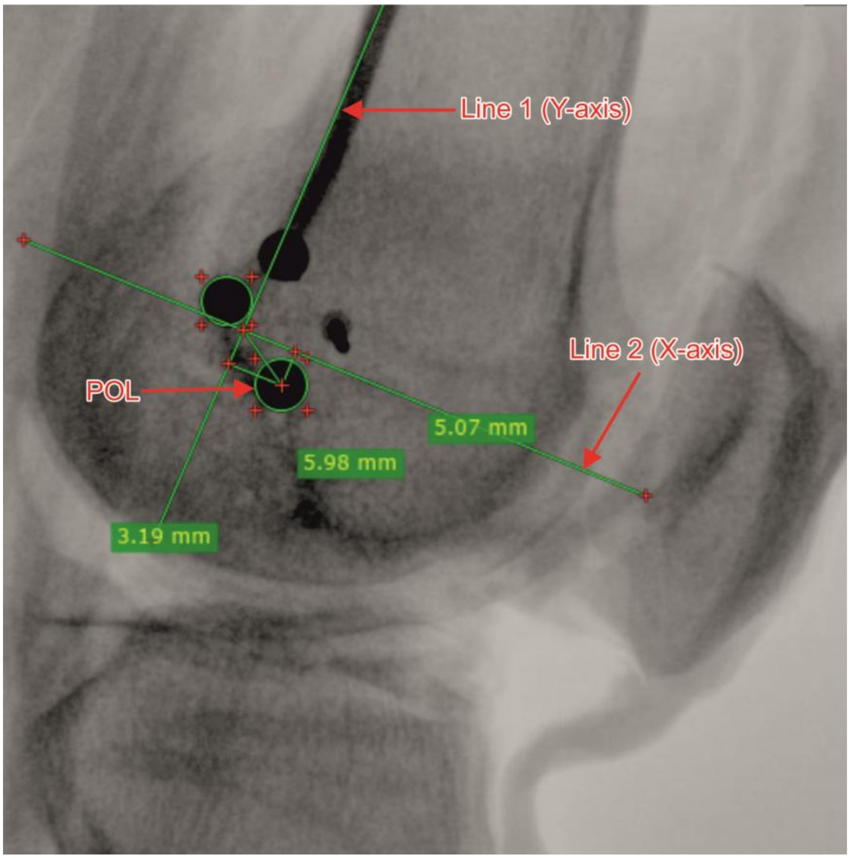


Figure 19 shows the radiological measurements of POL by Wijdicks et al.[4] technique in lateral view.

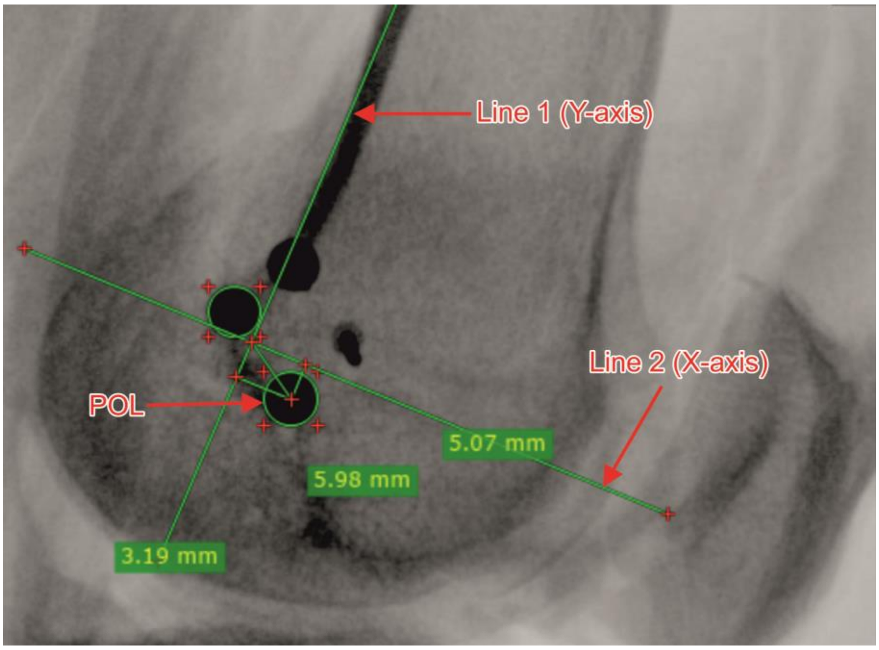


Figure 20 shows the radiological measurements of POL by KK Athwal et al.[8] technique in lateral view.

	STUDIES	RADIOLOGICAL TECHNIQUE USED
MPFL	Wijdicks et al. [4]	• Qualitative, only in lateral view, (in quadrants, formed by Line1 [Y-axis]; posterior femoral cortex extension line, Line2 [X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) • Quantitative, from the bony landmark (ME) and reference lines on femur and tibia in both AP and Lateral view x-rays

Table 3: Radiological techniques used for medial patellofemoral ligament (MPFL).

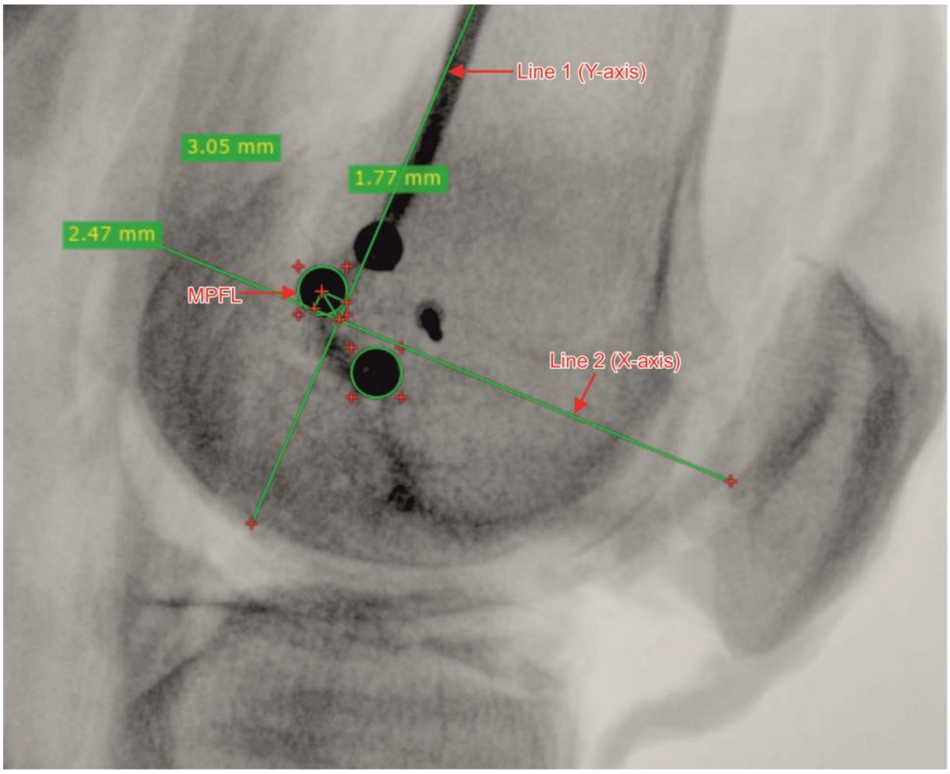


Figure 21 shows the radiological measurements of MPFL by Wijdicks et al.[4] technique in lateral view.

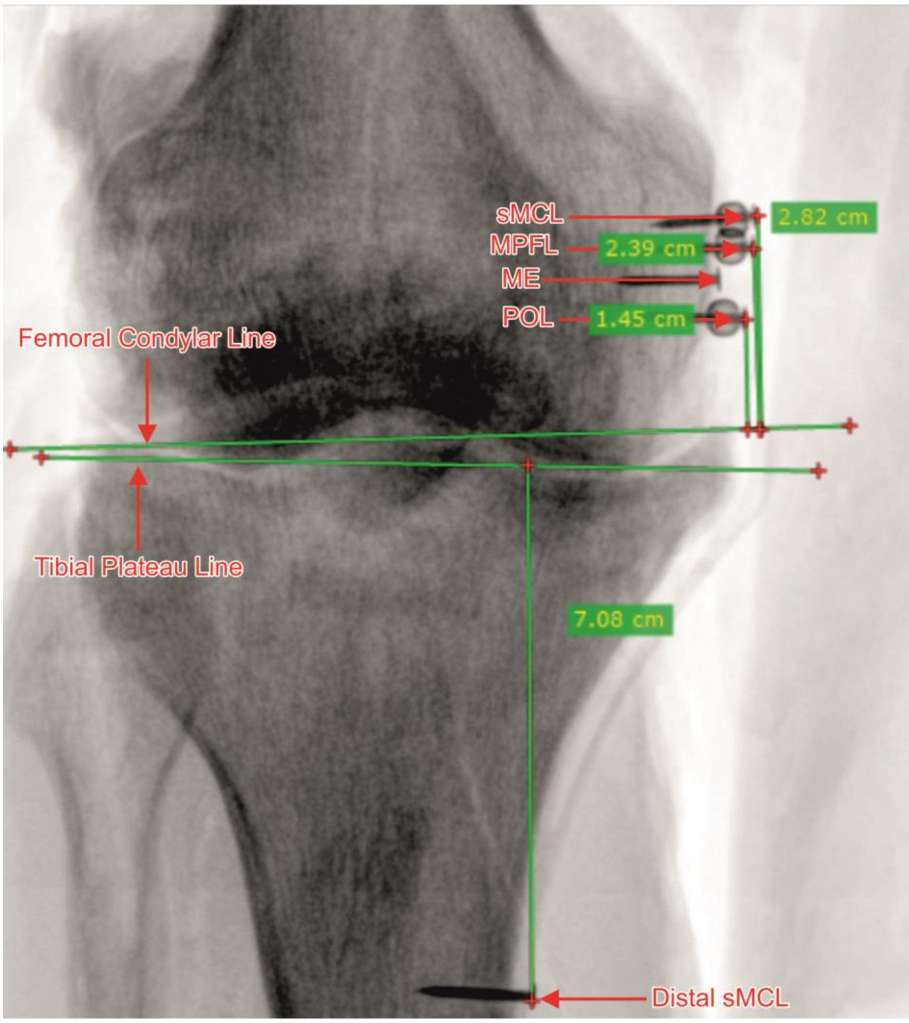


Figure 22 shows the radiological measurements of sMCL, POL, and MPFL by Wijdicks et al.[4] technique in the anteroposterior view.

The radiographic landmarks for lateral knee ligaments were marked according to the methods described by the following authors.

	STUDIES	RADIOLOGICAL TECHNIQUE USED
LCL	Pietrini et al. [3]	• Qualitative, only in lateral view, (in quadrants, formed by Line1[Y-axis]; posterior femoral cortex extension line, Line2 [X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) • Quantitative, from the bony landmark (LE) and reference lines on femur and fibula in both AP and Lateral view x-rays.
	Kremen et al. [9]	• Quantitatively in percentages on lateral image based on Line 1 [X-axis]; The line along the blumensaat line from anterior-most point to posterior-most point of the lateral femoral condyle (LFC) and Line 2 [Y-axis]; Perpendicular bisector to line 1 up to the inferior margin of the lateral femoral condyle (LFC)

Table 4: Radiological techniques used for lateral collateral ligament (LCL).

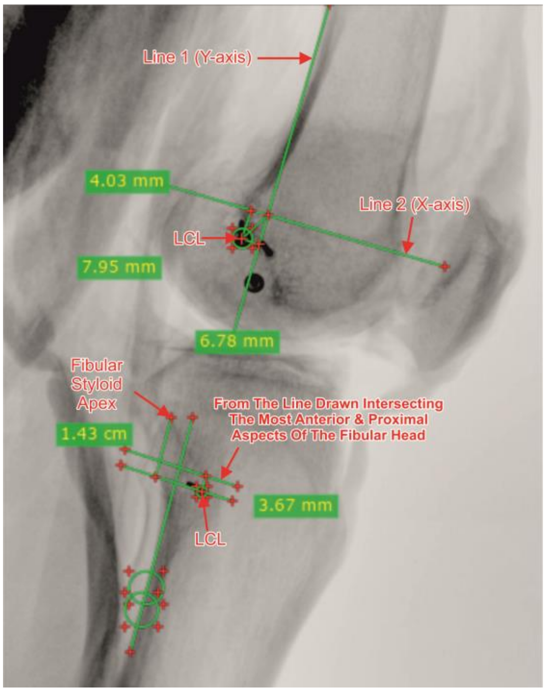


Figure 23 shows the radiological measurements of LCL by Pietrini et al.[3] technique in lateral view.

	STUDIES	RADIOLOGICAL TECHNIQUE USED
PT	Pietrini et al. [3]	• Qualitative, only in lateral view, (in quadrants, formed by Line1[Y-axis]; posterior femoral cortex extension line, Line2 [X-axis]; line perpendicular to line 1 passing through the posterior-most point of blumensaat point) • Quantitative, from the bony landmark (LE) and reference lines on femur and fibula in both AP and Lateral view x-rays.
	Kremen et al. [9]	• Quantitatively in percentages on lateral image based on Line 1 [X-axis]; The line along the blumensaat line from anterior-most point to posterior-most point of the lateral femoral condyle (LFC) and Line 2 [Y-axis]; Perpendicular bisector to line 1 up to the inferior margin of the lateral femoral condyle (LFC)

Table 5: Radiological techniques used for popliteal tendon (PT).

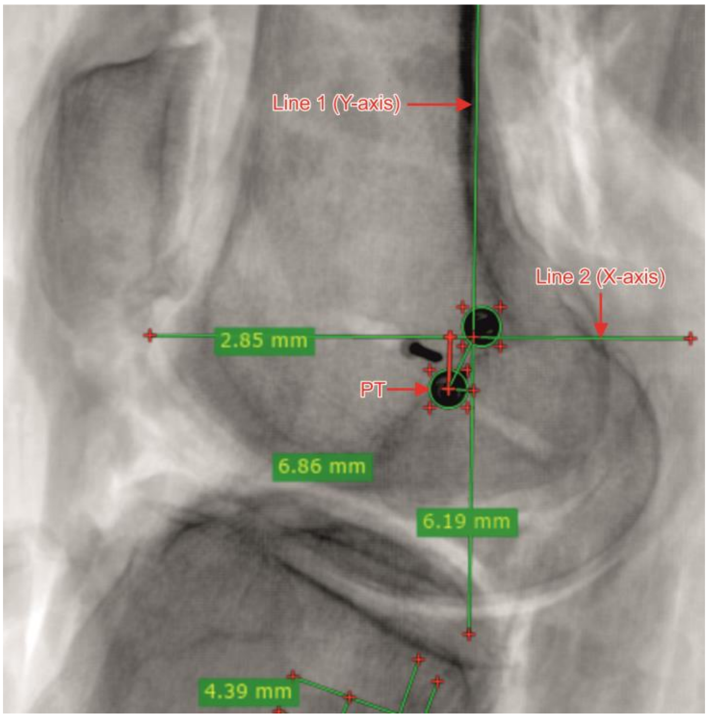


Figure 24 shows the radiological measurements of PT by Pietrini et al.[3] technique in lateral view.

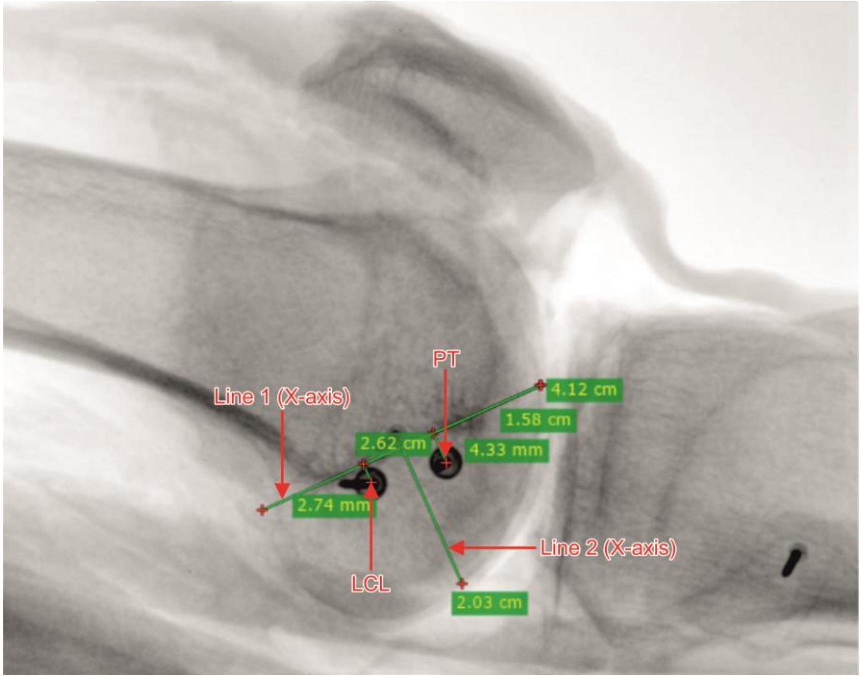


Figure 25 shows the radiological measurements of LCL and PT by Kremen et al.[9] technique in lateral view.

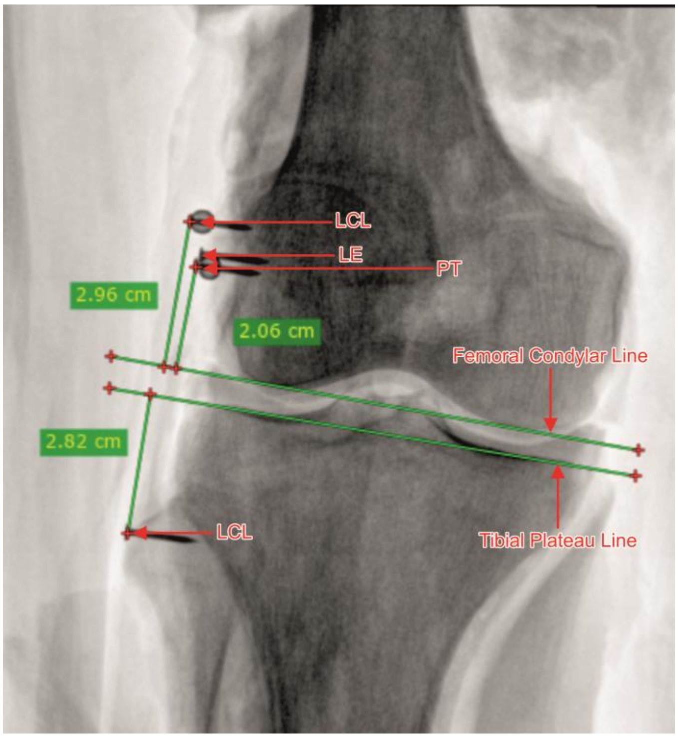


Figure 26 shows the radiological measurements of LCL and PT by Pietrini et al.[3] technique in the anteroposterior view.

The anatomical measurements from the bony landmarks to the footprints of ligaments and radiographic measurements based on some of the previously published author techniques were measured on the fluoroscopic images. All the measurements were done by two independent observers (1: 3rd-year junior resident and 2: 2nd-year senior resident) twice with an interval of 2 weeks to assess the Intra-observer and Inter-observer correlation. Each observer was blinded to the other's readings to avoid bias.

RESULTS

The present observational study was designed to find the correlation between the gross anatomical and radiological evaluation of medial and lateral ligaments of the knee joint in Indian cadavers. The sample size included 18 knees (9 cadavers) with a mean age of 79.7 ± 11.16 years (Range, 65-100 years) and three female, and six male cadavers, which were grossly and anatomically normal and formalin treated.

All 18 cadaveric knees were dissected to study the ligaments of interest. Fluoroscopic images were taken for which anatomical measurements were made using landmarks and radiological measurements based on commonly used published techniques. The Radiant Dicom software (Medixant, version 2022.1.1 64-bit) was used for this purpose.

A) Anatomical Measurements Results

Lateral Collateral Ligament (LCL)

	1st Observer		2nd Observer	
	1st Observation	**2nd Observation**	**1st Observation**	**2nd Observation**
Mean	7.52	7.60	8.45	7.52
SD	1.09	1.12	1.23	1.09
Max	9.75	9.85	10.1	9.75
Min	5.89	5.82	5.96	5.89

Table 6: Anatomical measurements (Linear distance) of lateral collateral ligament from bony landmark (Lateral epicondyle).

Anatomical measurements (Linear distance) of the lateral collateral ligament from the lateral epicondyle are shown in Table 6. The mean and standard deviation values of linear distance measured are 7.52±1.09 and 7.60±1.12 for the first observer in 1st and 2nd observations respectively, and 8.45±1.23 and 7.52±1.09 by the second observer in 1st and 2nd observations respectively. The maximum and minimum distances measured are 9.75 and 5.89 as the first observation made by the first observer and 9.85 and 5.82 as second observation of first observer. The second observer had 10.1 as maximum and 5.96 as the minimum in first observation and 9.75 as maximum and 5.89 as the minimum in second observation

	1st Observer				2nd Observer			
	X-Axis		Y-Axis		X-Axis		Y-Axis	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-6.25	-6.24	1.55	1.66	-7.10	-6.25	1.73	1.55
SD	2.36	2.35	3.40	3.44	3.13	2.36	4.12	3.40
Max	1.62	1.52	8.06	8.05	3.62	1.62	7.06	8.06
Min	-8.61	-8.71	-7.52	-7.42	-10.35	-8.61	-8.52	-7.52

Table 7: Anatomical measurements of lateral collateral ligament from bony landmark (Lateral epicondyle) in X and Y- axes.

Table 7 represents anatomical measurements of the lateral collateral ligament from the lateral epicondyle in the X and Y axes. The measurements of the lateral collateral ligament are -6.25±2.36 and -6.24±2.35 as the two observations made by the first observer on the X-axis. The mean distance and standard deviation measured are 1.55±3.40 and 1.66±3.44 by the first observer on the Y axis in the 1st and 2nd observations, respectively. Similarly, the first observation made by the second observer on the X axis is -7.10±3.13 and the second observation by the second observer on the X axis is -6.25±2.36. 1.73±4.12; 1.55±3.40 are the measurements on the Y axis in the 1st and 2nd observations by the second observer. The maximum and minimum values are 1.62; -8.61 and 1.52; -8.71 in the 1st and 2nd observations on the X axis by the first observer; and 8.06; -7.52 and 8.05; -7.42 in the 1st and 2nd observations on the Y axis by the first observer. The second observer had found 3.62;-10.35 and 1.62; -8.61 on the X axis and 7.06; -8.52 and 8.06; -7.52 as the maximum and minimum in the first observation and the second observation, respectively.

Popliteal Tendon (PT)

	1st Observer		2nd Observer	
	1st Observation	**2nd Observation**	**1st Observation**	**2nd Observation**
Mean	9.02	8.98	9.62	9.02
SD	2.49	2.69	2.35	2.49
Max	16.1	16.9	15.12	16.1
Min	5.66	5.89	5.62	5.66

Table 8: Anatomical measurements (Linear distance) of popliteal tendon from bony landmark (Lateral epicondyle).

Table 8 represents Anatomical measurements (Linear distance) of the popliteal tendon from the lateral epicondyle. The linear distance measured are 9.02±2.49 and 8.98±2.69 for first observer in 1st and 2nd observations respectively, and 9.62± 2.35 and 9.02±2.49 by the second observer in 1st and 2nd observations respectively. The maximum and minimum distances measured are 16.1 and 5.66 as the first observation made by first observer and 16.9 and 5.89 the as second observation by the first observer. The second observer had noticed 15.12 as the maximum and 5.62 as the minimum distance after first observation and 16.1 and the 5.66 as second observation.

	1st Observer				**2nd Observer**			
	X-Axis		**Y-Axis**		**X-Axis**		**Y-Axis**	
	1st Observation	**2nd Observation**	**1st Observation**	**2nd Observation**	**1st Observation**	**2nd Observation**	**1st Observation**	**2nd Observation**
Mean	-5.46	-5.45	-6.36	-6.46	-5.75	-5.46	-6.97	-6.36
SD	3.08	3.13	2.89	3.04	3.03	3.08	2.96	2.89
Max	-1.75	-1	-1.34	-1.44	-0.89	-1.75	-2.34	-1.34
Min	-13.3	-13.5	-11.5	-11.9	-14.1	-13.3	-12.9	-11.5

Table 9: Anatomical measurements of popliteal tendon from bony landmark (Lateral epicondyle) **in** X and Y- axes.

Table 9 represents anatomical measurements of the popliteal tendon from the bony landmark (lateral epicondyle) in the X and Y axes. For two observations made by the first observer for the X-axis, the mean and standard deviation are -5.46±3.08, and -6.36±2.89. The mean distance and standard deviation measured are -6.36±2.89 and -6.46±3.04, which are the two observations made by the first observer on the Y-axis. Similarly, the first and second observations made by the second observer on the X axis include the mean and standard deviations of -5.75±3.03 and -5.46±3.08 and -6.97±2.97 and -6.36±2.89 on the Y axis, respectively. The maximum and minimum values are -1.75, -13.3, and -1, -1.35 as the first observation on the X axis, and -1.34, -11.5, -1.44, and -11.9, respectively, as the first and second observation made by the first observer on the Y axis. The second observer had found -0.89, -14.1, and -1.75, -13.3, on the X axis, and -2.34, -12.9, and -1.34, -11.5, as the maximum and minimum after the first and second observations, respectively.

Superficial Medial Collateral Ligament (sMCL)

	1st Observer		**2nd Observer**	
	1st Observation	**2nd Observation**	**1st Observation**	**2nd Observation**
Mean	7.37	7.47	8.08	7.37
SD	1.44	1.38	1.11	1.44
Max	10.1	10.19	10.1	10.1
Min	4.57	4.9	5.57	4.57

Table 10: Anatomical measurements (Linear distance) of superficial medial collateral ligament from bony landmark (Medial epicondyle).

The anatomical measurements (linear distance) of the superficial medial collateral ligament from the medial epicondyle are represented in Table 10. The linear distances measured are 7.37±1.44 and 7.47±1.38 in 1st and 2nd observation respectively by the first observer and 8.08±1.11 and 7.37± 1.44 by the second observer in 1st and 2nd observations, respectively. The maximum and minimum distances measured are 10.1 and 4.57 as the first observation made by the first observer and 10.19 and 4.9 as the second observation by the first observer. The second observer had noticed 10.1 as the maximum and 5.57 as the minimum distance in first observation and 10.1 and 4.57 as the second observation.

	1st Observer				2nd Observer			
	X-Axis		**Y-Axis**		**X-Axis**		**Y-Axis**	
	1st Observation	**2nd Observation**	**1st Observation**	**2nd Observation**	**1st Observation**	**2nd Observation**	**1st Observation**	**2nd Observation**
Mean	-4.36	-4.29	0.25	0.30	-4.56	-4.36	0.62	0.25
SD	3.62	3.65	5.08	5.28	4.67	3.62	6.08	5.08
Max	1.79	1.96	6.6	6.9	4.49	1.79	8.01	6.6
Min	-8.16	-8.19	-7.2	-7.9	-9.69	-8.16	-8.2	-7.2

Table 11: Anatomical measurements of superficial medial collateral ligament from bony landmark (Medial epicondyle) in X and Y- axes.

Table 11 shows the anatomical measurements of the superficial medial collateral ligament from a bony landmark (the medial epicondyle) in the x and y axes. The measurements of the superficial medial collateral ligament from a bony landmark (medial epicondyle) on the x and y axes are -4.36±3.62, and -4.29±3.65 for two observations made by the first observer for the X axis. The mean distance and standard deviation measured are 0.25±5.08 and 0.30±5.28 by the first observer on the Y axis, respectively. Similarly, the first observations made by the second observer on the X axis include means and standard deviations of -4.56±4.67, -4.36±3.62, on the X axis, and 0.62±6.08, and 0.25±5.08, on the Y axis. The maximum and minimum values are 1.79 and -8.16; 1.96 and -8.19 for the first observation on the X axis; 6.6 and -7.2; 6.9 and -7.9 for the first and second observations on the Y axis, respectively. The second observer found 4.49 and -9.69; 1.79 and -8.16 on the X axis; 8.01 and -8.2; and 6.6 and -7.2 as the maximum and minimum after the first observation and second observation, respectively.

Posterior Oblique Ligament (POL)

	1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	12.90	12.68	12.40	12.90
SD	3.37	3.24	2.83	3.37
Max	16.6	16.61	15.6	16.6
Min	6.2	6.6	7.2	6.2

Table 12: Anatomical measurements (Linear distance) of posterior oblique ligament from bony landmark (Medial epicondyle).

Table 12 represents the anatomical measurements (linear distance) of the posterior oblique ligament from the medial epicondyle. The linear distance of the posterior oblique ligament measured are 12.90±3.37 and 12.68±3.24 as the two observations made by the first observer. The linear distance measured is 12.40±2.83 and 12.90±3.37 as the two observations made by the second observer respectively. The maximum and minimum distances measured are 16.6 and 6.2 as the first observation, 16.61 and 6.6 as the maximum and minimum distance respectively as the second observation made by the first observer. The second observer had noticed 15.6 as the maximum and 7.2 as the minimum distance after first observation and 16.6 and 6.2 as the second observation.

	1st Observer				2nd Observer			
	X-Axis		Y-Axis		X-Axis		Y-Axis	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-11.50	-11.56	-0.49	-0.47	-11.08	-11.50	-0.64	-0.49
SD	4.42	4.44	5.18	5.13	3.73	4.42	5.32	5.18
Max	-1.42	-1.49	9.36	9.31	-2.42	-1.42	8.36	9.36
Min	-16.6	-16.67	-9.35	-9.34	-15.4	-16.6	-9.31	-9.35

Table 13: Anatomical measurements of posterior oblique ligament from bony landmark (Medial epicondyle) in X and Y- axes.

Table 13 shows the observations made by two observers for the anatomical measurements of the posterior oblique ligament from the bony landmark (medial epicondyle) in the X and Y axes. The posterior oblique ligament measurements in the x and y axes, in means and standard deviations, are -11.50±4.42 and -11.56±4.44 for two observations made by the first observer for the x-axis. The mean distance and standard deviation measured are -0.49±5.18 and -0.47±5.13 by the first observer on the Y axis, respectively. Similarly, the second observer's first observations on the X axis include mean and standard deviations of -11.08±3.73; -11.50±4.42; on the X axis and -0.64±5.32; -0.49±5.18 on the Y axis. The maximum and minimum values are -1.42 and -16.6; -1.49 and -16.67 and 9.36; -9.35 and 9.31; -9.34 as first and second observations made by the first observer on the X and Y axis. The second observer found -2.42; -15.4 and -1.42; -16.6 on X-axis and 8.36;-9.31 and 9.36, and -9.35 as the maximum and minimum after the first observation and second observation respectively.

Medial Patellofemoral Ligament (MPFL)

	1st Observer		2nd Observer	
	1st Observations	2nd Observations	1st Observations	2nd Observations
Mean	7.34	7.21	7.88	7.34
SD	2.06	2.16	1.68	2.06
Max	11	11.9	10	11
Min	3.97	2.97	4.83	3.97

Table 14: Anatomical measurements (Linear distance) of medial patellofemoral ligament from bony landmark (Medial epicondyle).

Table 14 shows anatomical measurements (linear distance) of the medial patellofemoral ligament from the medial epicondyle. The mean linear distance and standard deviation of the of medial patellofemoral ligament measured are 7.34±2.06 and 7.21±2.16 as two observations made by the first observer. The mean linear distance and standard deviation measured are 7.88±1.68 and 7.34±2.06 by the second observer. The maximum and minimum distances measured are 11 and 3.97 as the first observation, 11.9 and 2.97 as second observation made by the first observer. The second observer had noticed 10 as the maximum and 4.83 as the minimum distance after the first observation and 11 and the 3.97 as second observation.

	1st Observer				2nd Observer			
	X-Axis		Y-Axis		X-Axis		Y-Axis	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	1.18	1.11	2.70	2.62	1.61	1.18	2.82	2.70
SD	5.47	5.39	4.68	4.83	6.19	5.47	4.59	4.68
Max	7.36	7.31	10.9	10.9	8.89	7.36	9.9	10.9
Min	-8.93	-8.91	-7.03	-7.9	-9.93	-8.93	-8.03	-7.03

Table 15: Anatomical measurements of medial patellofemoral ligament from bony landmark (Medial epicondyle) in X and Y- axes.

Table 15 shows anatomical measurements of the medial patellofemoral ligament from the bony landmark (medial epicondyle) in the X and Y-axis. The measurements of the medial patellofemoral ligament on the X and Y axes, values are in mean± standard deviations are 1.18±5.47 and 1.11±5.39 on the X-axis, and 2.70±4.68; 2.62±4.83 for the two observations made by the first observer on the Y axis. The mean distance and standard deviation measured are 1.61±6.19; 1.18±5.47 by the second observer on the X and Y axis, respectively. Similarly, the second observer's observations on the X axis include mean and standard deviations of 1.616.19 and 1.185.47 for the first observation and 2.824.59 and 2.704.68 for the second observation on the Y axis, respectively. The maximum and minimum values are 7.36 and -8.93 as the first observation on the X axis, 7.31 and -8.91; 10.9 and -7.03 and 10.9; -7.9. The values 8.89;-9.93, and 7.36;-8.93 as the first and second observations made by the first and second observers on the X and Y axis. The second observer found 9.9; -8.03, and 10.9;-7.03 on the X-axis and Y-axis as the maximum and minimum values, respectively.

INTRA-OBSERVER CORRELATION COEFFICIENT FOR ANATOMICAL MEASUREMENT RESULTS

	Intra-observer pearson's correlation coefficient (r)	**Comment**
LCL	0.989	Very strong positive correlation
PT	0.987	Very strong positive correlation

Table 16 Intra-observer pearson's correlation coefficient of anatomical measurements (Linear distance) of lateral knee ligaments from bony landmark (Lateral epicondyle).

Table 16 shows the intra-observer Pearson's correlation coefficient of anatomical measurements (linear distance) of lateral knee ligaments from a bony landmark (lateral epicondyle). The intra-observer Pearson's correlation coefficient for LCL was 0.989, and 0.987 for PT. For intra-observer comparison, we discovered a very strong positive correlation between LCL and PT.

	Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	0.995	Very strong positive correlation
POL	0.992	Very strong positive correlation
MPFL	0.965	Very strong positive correlation

Table 17 Intra-observer pearson's correlation coefficient of anatomical measurements (Linear distance) of medial knee ligaments from bony landmark (Medial epicondyle).

Table 17 represents the intra-observer Pearson's correlation coefficient of anatomical measurements (linear distance) of medial knee ligaments from a bony landmark (the medial epicondyle). The intra-observer comparison of sMCL, POL, and MPFL was found to be very strong, with Pearson coefficient values of 0.995, 0.992, and 0.965, respectively.

INTER-OBSERVER CORRELATION COEFFICIENT FOR ANATOMICAL MEASUREMENT RESULTS

There was no difference in the intra-observer correlation coefficient between the first and second observation for both observers. Therefore, we only considered the first observation of both observers when calculating the inter-observer correlation coefficient.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	Comment
LCL	0.686	Strong correlation
PT	0.909	Very strong positive correlation

Table 18: Inter-observer (1st & 2nd) pearson's correlation coefficient of anatomical measurements (Linear distance) of lateral knee ligaments from bony landmark (Lateral epicondyle).

Table 18 represents the inter-observer (1st and 2nd) Pearson's correlation coefficient of anatomical measurements (linear distance) of lateral knee ligaments from a bony landmark (lateral epicondyle). In our study, we discovered a strong and very strong positive correlation for LCL with r = 0.686. A similar trend of very strong positive correlation was observed for PT, with r = 0.909.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	**Comment**
sMCL	0.641	Strong correlation
POL	0.974	Very strong positive correlation
MPFL	0.874	Very strong positive correlation

Table 19: Inter-observer (1st & 2nd) pearson's correlation coefficient of anatomical measurements (Linear distance) of medial knee ligaments from bony landmark (Medial epicondyle).

Table 19 represents the inter-observer (1st and 2nd) Pearson's correlation coefficient of anatomical measurements (linear distance) of medial knee ligaments from a bony landmark (medial epicondyle). In our study, we discovered a strong and very strong positive correlation for sMCL with r = 0.641. A similar trend of very strong positive correlation was observed for POL with r = 0.974 and for MPFL a very strong positive correlation was found in our study with r = 0.874.

P-VALUE FOR ANATOMICAL MEASUREMENTS RESULTS

Ligament	**Current study (Mean ± SD)**	**Peitrini et al.[3] (Mean)**	**P-value by unpaired t-test**
LCL	7.52 ± 1.09	4.3	-
PT	9.02 ± 2.49	12.2	-

Table 20 P-values for anatomical measurements (Linear distance) of lateral knee ligaments from bony landmark (Lateral epicondyle).

Anatomical measurements (linear distance) of the lateral knee ligaments from a bony landmark are depicted in Table 20. (Lateral epicondyle). We obtained readings for LCL and PT of 7.52±1.09 and 9.02±2.49. In their 2009 study, Peitrini et al.reported that the mean values for LCL and PT were, respectively, 4.3 and 12.2. Numerically, the mean LCL and PT measurements appear to be higher than those reported by Peitrini et al.However, the p-value cannot be calculated because SD was not provided in their study.

Ligament	Current study (Mean ± SD)	Wijdicks et al.[4] (Mean ± SD)	P-value by unpaired t-test
sMCL	7.37±1.44	6.0 ± 0.8	0.0075 (Significant)
POL	12.9±3.37	18.1±2.8	0.0002 (Significant)
MPFL	7.34±2.06	15.9±3.2	0.0001 (Significant)

Table 21: P-values for anatomical measurements (Linear distance) of medial knee ligaments from bony landmark (Medial epicondyle).

Table 21 displays the P-values for the anatomical measurements (linear distances) of the medial knee ligaments from the medial epicondyle, a bony landmark. The sMCL, POL, and MPFL mean and standard deviation values in our study are 7.37±1.44, 12.9±3.37, and 7.34±2.06. In research by Wijdickes et al.[4] the mean and SD values for sMCL, POL, and MPFL were 6.0±0.8, 18.1±2.8, and 15.9±3.2, respectively. Using a t-test, we discovered a highly significant difference in the measurements of sMCL, POL, and MPFL with p values of 0.0075, 0.0002, and 0.0001, respectively.

B) RADIOLOGICAL MEASUREMENTS RESULTS

LATERAL COLLATERAL LIGAMENT (LCL)

	X-axis				Y-axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-6.09	-6.02	-6.45	-6.09	-4.5	-4.87	-4.73	-4.5
SD	4.38	4.15	3.91	4.38	5.51	5.65	5.72	5.51
Max	-1.06	-1.02	-2.01	-1.06	6.3	5.87	4.3	6.3
Min	-15.2	-14.2	-14.4	-15.2	-12.8	-13.3	-14.3	-12.8

Table 22a: Radiological measurements of lateral collateral ligament by Pietrini et al.[3] method in lateral view.

Table 22a shows the radiological measurements of the lateral collateral ligament by the Pietrini et al.[3] method in lateral view. The mean±SD for first and second observers in both observations on the X axis are -6.09±4.38 and -6.45±3.91 and -6.02±4.15; -6.09±4.38 respectively. The mean±SD for the first and second observers in both observations on Yaxis are -4.5±5.51 and -4.73±5.72 and -4.87±5.65 and -4.5±5.511 respectively. The maximum and minimum values for X axis found by the first and second observer in both observations are -1.06,-15.2 and -2.01,-14.4 and -1.02,-14.2 and -1.06 and -15.2 respectively. The maximum and minimum values for the Y axis found by the first and second observer in both observations are 6.3,-12.8 and 4.3,-14.3 and 5.87,- 13.3 and 6.3, -12.8, respectively.

	FROM THE FEMORAL CONDYLAR LINE				FROM THE TIBIAL PLATEAU LINE			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	26.91	26.92	27.02	26.91	31.15	31.06	31.42	31.15
SD	5.64	5.61	5.45	5.64	7.01	6.78	6.51	7.01
Max	35.4	35.14	34.4	35.4	40.5	39.5	41.5	40.5
Min	16	16.01	17	16	16	16.1	19	16

Table 22b: Radiological measurements of lateral collateral ligament by Pietrini et al.[3] method in antero-posterior view.

Table 22b shows radiological measurements of lateral collateral ligament by pietrini et al.[3] method ianteroposterioror view. The mean±SD for first and second observations from the femoral condylar line and from the tibial plateau line are 26.91±5.64 and 27.02 ±5.45 and 26.92±5.61; 26.91±5.64 respectively. The mean±SD for first and second observations are 31.15±7.01 and 31.42±6.51 and 31.06±6.78 and 31.15±7.01. The maximum and minimum values are 35.4, 16 and 34.4, 17 and 35.14, 16.01 and 35.4,16. The maximum and minimum values found by Ist and 2nd observers are 40.5,16.and 41.5, 19 ; 39.5, 16.1 and 40.5, 16 respectively.

	From fibular styloid apex				From the line drawn intersecting the most anterior & proximal aspects of the fibular head			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	11.29	10.94	11.62	11.29	5.23	5.35	5.78	5.23
SD	4.70	3.42	3.98	4.70	3.56	3.52	3.05	3.56
Max	19.5	15.51	18.5	19.5	13	13.9	12	13
Min	4.62	5.62	5.62	4.62	0.53	1.01	1.53	0.53

Table 22 c: Radiological measurements of distal fibular attachments of lateral collateral ligament by Pietrini et al.[3] method in lateral view.

Table 22c shows the radiological measurements of distal fibular attachments of lateral collateral ligament by Pietrini et al.[3] method in lateral view. The mean±sd for first and second observations from the from fibular styloid apex are 11.29±4.70 and 11.62 ±3.98 and 10.94±3.42; 11.29±4.70 respectively. The maximum and minimum values are 19.5, 4.62 and 18.5, 5.62 and 15.51, 5.62 and 19.5, 4.62. The observations made after line drawn intersecting the most anterior & proximal aspects of the fibular head are represented 5.23± 3.56 and 5.78 ±3.05 and 5.35±3.52; 5.23±3.56 respectively. The maximum and minimum values are 13, 0.53; 12, 1.53 and 13.9, 1.01 and 13, 0.53 respectively.

	X-axis				Y-axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	70.15	70.19	69.92	70.15	10.77	10.94	10.60	10.77
SD	14.45	14.45	14.43	14.45	17.98	18.35	17.37	17.98
Max	91.3	90.3	92.3	91.3	35.5	35.7	36.5	35.5
Min	48.3	48.5	47.3	48.3	-17.2	-17.6	-16.2	-17.2

Table 23: Radiological measurements of lateral collateral ligament by kremen et al.[9] method in lateral view.

Table 23 shows radiological measurements of lateral collateral ligament by Kremen et al.[9] method in lateral view. The mean±sd for first and second observations on X axis are 70.15±14.45 and 69.92 ±14.43 and 70.19±14.45; 70.19±14.45 respectively. The maximum and minimum values are 91.3, 48.3 and 92.3, 47.3 and 90.3, 48.5 and 91.3 and 48.3 respectively. The observations made using Y axis are represented as10.77±17.98 and 10.94 ±18.35 and 10.77±17.98 respectively. The maximum and minimum X axis values are 91.3, 48.3;92.3,47.3 and 90.3,48.5. The maximum and minimum values observed for Y axis included 35.5,-17.2; 36.5,-16.2 and 35.7,-17.6; 35.5,-17.2 respectively.

POPLITEAL TENDON (PT)

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-5.10	-5.11	-5.46	-5.10	-11.81	-11.87	-12.49	-11.81
SD	5.67	5.91	6.04	5.67	5.90	5.92	5.96	5.90
Max	5.33	4.33	5.67	5.33	0.8	1.8	1.8	0.8
Min	-13.7	-14.7	-14.9	-13.7	-20.2	-21.2	-21.01	-20.2

Table 24a: Radiological measurements of popliteal tendon by Pietrini et al.[3] method in lateral view.

Table 24a represents the radiological measurements of popliteal tendon by Pietrini et al.[3] method in lateral view. The mean±sd for first and second observations on X axis are -5.10±5.67and -5.46±6.04 and -5.11±5.91; -5.10±5.67 respectively. The maximum and minimum values observed for X axis are 5.33,-13.7; 5.67,-14.9 and 4.33,-14.7, 5.33,-13.7 respectively. The observations made using Y axis are represented as -11.81±5.90 and -12.49 ±5.96 and -11.87±5.92; -11.81, 5.90 respectively. The maximum and minimum X axis values are the maximum and minimum values observed for Y axis included 0.8,-20.2; 1.8,-21.2; 1.8,-21.2 and 0.8,-20.2 respectively.

	From femoral condylar line			
	1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	16.53	16.26	16.90	16.53
SD	5.63	5.70	5.67	5.63
Max	29.5	28.6	27.6	29.5
Min	10.4	10.6	9.2	10.4

Table 24b: Radiological measurements of popliteal tendon by Pietrini et al.[3] method in antero-posterior view.

Table 24b represents radiological measurements of popliteal tendon by pietrini et al.[3] method in antero-posterior view from femoral condylar line. The mean±sd for first and second observations are 16.53±5.63and 16.90± 5.67 and 16.26±5.70 and 16.53±5.63 respectively. The maximum and minimum values observed are 29.5, 10.4; 27.6, 9.2 and 28.6, 10.6 and 29.5, 10.4 respectively.

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	52.47	52.41	52.39	52.47	29.62	30.43	30.32	29.62
SD	15.70	15.58	15.40	15.70	22.93	22.98	21.97	22.93
Max	84.3	84.1	82.9	84.3	79.1	79.9	78.2	79.1
Min	31.8	32.8	32.8	31.8	-14.4	-13.4	-15.4	-14.4

Table 25: Radiological measurements of popliteal tendon by Kremen et al.[9] method in lateral view.

Table 25 shows the radiological measurements of popliteal tendon by KREMEN et al. , [9] method in lateral view. The mean±sd for first and second observations on X axis are -52.47±15.70 and 52.39±15.40 and 52.41±15.58; 52.47±15.70 respectively. The maximum and minimum values observed for X axis are 84.3, 31.8; 82.9, 32.8; 84.1, 32.8 anf 84.1, 32.8 respectively. The observations made using Y axis are represented as 29.62±22.93 and 21.97 ±78.2 and 22.98±79.9; 22.9379.respectively. The maximum and minimum Yaxis values are The maximum and minimum values observed for Y axis are 79.1, -14.4; 78.2,15.4; 79.9,-13.4 and 79.1,-14.4 respectively.

SUPERFICIAL MEDIAL COLLATERAL LIGAMENT (sMCL)

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	3.06	3.14	3.14	3.06	-3.53	-3.86	-3.91	-3.53
SD	6.74	6.71	6.84	6.74	5.64	5.69	5.70	5.64
Max	15.4	14.4	14.3	15.4	5.47	5.03	6.21	5.47
Min	-6.97	-6.33	-7.28	-6.97	-15.1	-14.1	-14.2	-15.1

Table 26a: Radiological measurements of superficial medial collateral ligament by Wijdicks et al.[4] method in lateral view.

Table 26a shows the radiological measurements of superficial medial collateral ligament by wijdicks et al.[4] method in lateral view. The mean±SD values are 3.06±6.74; 3.14±6.84, 3.14±6.71, and 3.06±6.74 respectively for X- axis observations. The mean±SD for Y axis observations of Ist and second observer are: -3.53±5.64, -3.91±5.70; -3.86±5.70 and -3.53±5.64 respectively. The maximum and minimum observed values are 15.4, -6.97; 14.3,-7.28; 14.4,-6.33; 15.4,-6.97 and for Y axis observations made are 5.47,-15.1; 6.21,-14.2; 5.03,-14.1, and 5.47,-14.1 respectively

	From the femoral condylar line				From the tibial plateau line			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	27.27	27.11	27.35	27.27	72.09	71.88	72.14	72.09
SD	5.23	5.63	5.46	5.23	14.20	14.03	13.49	14.20
Max	36.6	38.6	37.6	36.6	99.1	99.19	98.1	99.1
Min	19	19.2	20.5	19	52.6	52.06	53.6	52.6

Table 26b: Radiological measurements of superficial medial collateral ligament by Wijdicks et al.[4] method in antero-posterior view.

Table 26b shows radiological measurements of superficial medial collateral ligament by wijdicks et al.[4] method in antero-posterior view. From femoral condylar line the mean±sd for first and second observations are 27.27±5.23and 27.35±5.46 and 27.11±5.63 and 27.27±5.23 respectively. The maximum and minimum values observed are 36.6, 19; 37.6, 20.5 and 38.6, 20.5 and 36.6 and 19 respectively. From the tibial plateau line the observations made are 72.09±14.20; 72.14±13.49; 72.14±14.03; 71.88±14.03, and 72.09±14.20 respectively. The maximum and minimum values observed are 99.1,52.6;98.1;53.6;99.19,52.06;99.1and 52.6 respectively.

	From the medial tibial slope line				From mid-diaphyseal axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	66.87	67.28	67.37	66.87	-1.78	-2.07	-2.20	-1.78
SD	16.06	16.27	15.67	16.06	4.60	4.51	5.59	4.60
Max	98.9	99.9	99.9	98.9	5.94	5.16	6.94	5.94
Min	44.3	43.3	49.1	44.3	-7.65	-7.55	-9.65	-7.65

Table 26c: Radiological measurements of distal tibial attachments of superficial medial collateral ligament by Wijdicks et al.[4] method in lateral view.

Table 26c represents radiological measurements of distal tibial attachments of the superficial medial collateral ligament by Wijdicks et al.[4] method in lateral view from the medial tibial slope line the first and second observations made by both the observers are 66.87±16.06; 67.37±15.67; 67.28±16.27 and 66.87±16.06 respectively. The first and second observations made by second observer from mid diaphyseal axis are -1.78±4.60, -2.20±5.59,-2.07±4.51,-1.78±4.60 respectively. The maximum and minimum values observed are 98.9, 44.3; 99.9, 49.1 and 99.9, 43.3; 98.9, 44.3 and by second observer are 5.94,-7.65; 6.94,-9.65, 5.16,-7.55 and 5.94 and -7.65 respectively.

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	1.81	1.93	1.51	1.81	4.79	4.91	4.65	4.79
SD	5.78	5.86	6.27	5.78	5.19	5.35	4.70	5.19
Max	9.9	9.95	10.4	9.9	13.44	13.9	12.31	13.44
Min	-6.69	-6.61	-7.4	-6.69	-5.41	-6.41	-4.41	-5.41

Table 27: Radiological measurements of superficial medial collateral ligament by Hartshorn et al.[6] method in lateral view.

Table 27 shows radiological measurements of superficial medial collateral ligament by Hartshorn et al.[6] method in lateral view. The mean±SD values are 1.81±5.78; 1.51±6.27, 1.93±5.86, and 1.81±5.78 respectively for X- axis observations. The mean±SD for Y axis observations of second observer are: 4.79±5.19, 4.65±4.70; 4.91±5.35 and 4.79±5.19 respectively. The maximum and minimum observed values are 9.9,-6.69; 10.4,-7.4; 9.95,-6.61 and 9.9,-6.69 and for Y axis observations made are 13.44;-5.41, 12.31,-4.41; 13.9,-6.41 and 13.44,-5.41 respectively

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	3.06	3.14	3.14	3.06	-3.53	-3.86	-3.91	-3.53
SD	6.74	6.71	6.84	6.74	5.64	5.69	5.70	5.64
Max	15.4	14.4	14.3	15.4	5.47	5.03	6.21	5.47
Min	-6.97	-6.33	-7.28	-6.97	-15.1	-14.1	-14.2	-15.1

Table 28: Radiological measurements of superficial medial collateral ligament by KK Athwal et al.[8] method in lateral view.

Table 28 represents radiological measurements of superficial medial collateral ligament by KK Athwal et al.[8] method in lateral view. The mean±SD values are 3.06±6.74; 3.14±6.84, 3.14±6.71 and 3.06±6.74, respectively for X- axis observations. The mean±SD for Y axis observations of the second observer are: -3.53±5.64,-3.91±5.70; -3.86±5.69 and -3.53±5.64 respectively. The maximum and minimum observed values for X axis are 15.4,-6.97; 14.3,-7.28; 14.4,-6.33; 15.4,-6.97 and for Y axis observations made are 5.47,-15.1; 6.21,-14.2; 5.03,-14.1; 5.47 and -15.1 respectively.

POSTERIOR OBLIQUE LIGAMENT (POL)

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-3.52	-3.88	-3.72	-3.52	-4.09	-4.31	-4.39	-4.09
SD	9.23	9.59	9.82	9.23	4.16	4.15	4.58	4.16
Max	18.9	17.9	19.5	18.9	3.61	3.61	4.62	3.61
Min	-15.2	-16.2	-15.2	-15.2	-11.5	-12.5	-11.9	-11.5

Table 29a: Radiological measurements of posterior oblique ligament by Wijdicks et al.[4] method in lateral view.

Table 29a shows radiological measurements of posterior oblique ligament by Wijdicks et al.[4] method in lateral view. The mean±SD values are -3.52±9.23; -3.72±9.82, -3.88±9.59 and -3.52±9.23, respectively for X- axis observations. The mean±SD for Y axis observations of the second observer are : -4.09±4.16; -4.39±4.58; -4.31±4.15 and -4.09±4.16 respectively. The maximum and minimum observed values for X axis are 18.9,-15.2; 19.5,-15.2; 17.9,-16.2; 18.9, and -15.2 and for Y axis observations made are 3.16,-11.5;4.62,-11.9; 3.61,-12.5,3.61, and -11.5 respectively

	From the femoral condylar line			
	1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	28.88	29.08	29.65	28.88
SD	5.86	5.72	6.34	5.86
Max	40.1	39.1	41.1	40.1
Min	20.9	20.1	20.1	20.9

Table 29b: Radiological measurements of posterior oblique ligament by Wijdicks et al.[4] method in antero-posterior view.

Table 29b represents radiological measurements of posterior oblique ligament by Wijdicks et al.[4] method in antero-posterior view from femoral condylar line the Mean±SD for first and second observations are 28.88±5.86 and 29.65± 6.34 and 29.08±5.72 and 28.88±5.86 respectively. The maximum and minimum values observed are 40.1,20.9;41.1, 20.1; 39.1, 20.1;40.1,20.9 respectively.

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	-3.52	-3.88	-3.72	-3.52	-4.09	-4.31	-4.39	-4.09
SD	9.23	9.59	9.82	9.23	4.16	4.15	4.58	4.16
Max	18.9	17.9	19.5	18.9	3.61	3.61	4.62	3.61
Min	-15.2	-16.2	-15.2	-15.2	-11.5	-11.9	-12.5	-11.5

Table 30: Radiological measurements of posterior oblique ligament by KK Athwal et al.[8] method in lateral view.

Table 30 shows radiological measurements of posterior oblique ligament by KK Athwal et al.[8] method in lateral view the mean±SD values are -3.52±9.23; -3.72±9.82, -3.88±9.59 and -3.52±9.23, respectively for X- axis observations. The mean±SD for Y axis observations of the second observer are: -4.09±4.16; -4.39±4.58; -4.31±4.15 and -4.09±4.16 respectively. The maximum and minimum observed values for X axis are 18.9,-15.2; 19.5,-15.2; 17.9,-16.2; 18.9, and -15.2 and for Y axis observations made are 3.16,-11.5;4.62,-11.9; 3.61,-12.5,3.61, and -11.5 respectively.

MEDIAL PATELLOFEMORAL LIGAMENT (MPFL)

	X-Axis				Y-Axis			
	1st Observer		2nd Observer		1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	6.02	6.05	6.40	6.02	0.52	1.16	0.61	0.52
SD	7.176	7.38	7.64	7.17	4.42	4.93	4.61	4.42
Max	15.7	15.1	16.9	15.7	5.66	7.44	6.74	5.66
Min	-7.06	-7.99	-6.9	-7.06	-9.4	-9.9	-8.4	-9.4

Table 31a: Radiological measurements of medial patellofemoral ligament by Wijdicks et al.[4] method in lateral view.

Table 31a shows radiological measurements of medial patellofemoral ligament by Wijdicks et al.[4] method in lateral view. The mean±SD values are 6.02±7.176; 6.40±7.64,6.05±7.38 and 6.02±7.17, respectively for X- axis observations. The mean±SD for Y axis observations of the second observer are: 0.52±4.42; 0.61±4.61; 1.16±4.93 and 0.52±4.42 respectively. The maximum and minimum observed values for X axis are15.7,-7.06;16.9,-6.9;15.1,-7.99,15.7,-7.06 and for Y axis observations made for maximum and minimum values are 5.66,-9.4; 6.74, -8.4; 7.44,-9.9; 5.66 and -9.4 respectively.

	From the femoral condylar line			
	1st Observer		2nd Observer	
	1st Observation	2nd Observation	1st Observation	2nd Observation
Mean	31.46	31.19	32.07	31.46
SD	9.68	8.94	9.76	9.68
Max	52.1	51.1	55.1	52.1
Min	14.5	15.5	16.5	14.5

Table 31b: Radiological measurements of medial patellofemoral ligament by Wijdicks et al.[4] method in antero-posterior view.

Table 31b shows radiological measurements of medial patellofemoral ligament by Wijdicks et al.[4] method in antero-posterior view. From femoral condylar line the Mean±SD for first and second observations are 31.46±9.68 and 32.07± 9.76 and 31.19±8.94 and 31.46±9.68 respectively. The maximum and minimum values observed are 52.1, 14.5 and 55.1, 16.5 for first observer and 51.1, 15.5 and 52.1 and 14.5 for second observer respectively.

INTRA-OBSERVER CORRELATION COEFFICIENT FOR RADIOLOGICAL MEASUREMENT RESULTS

		Intra-Observer Pearson's Correlation Coefficient (r)	Comment
LCL	**X-axis**	0.997	Very strong positive correlation
	Y-axis	0.950	Very strong positive correlation
PT	**X-axis**	0.985	Very strong positive correlation
	Y-axis	0.984	Very strong positive correlation

Table 32a: Intra-observer pearson's correlation coefficient of radiological measurements of lateral knee ligaments by Pietrini et al. [3] in lateral view.

Table 32a shows the intra-observer Pearson's correlation coefficient for the radiological measurements of lateral knee ligaments by Pietrini et al.[3] in lateral view. The intra-observer Pearson's correlation coefficients for the X and Y axes of LCL and PT were 0.997, 0.950, and 0.985, 0.984, respectively, and we found a very strong positive correlation for measurements of distal fibular attachments of lateral knee ligaments using Pietrini et al. 's (2009) [3] technique in our study.

		Intra-Observer Pearson's Correlation Coefficient (r)	Comment
LCL	**From the femoral condylar line**	0.986	Very strong positive correlation
	From the tibial plateau line	0.973	Very strong positive correlation
PT	**From the femoral condylar line**	0.951	Very strong positive correlation

Table 32b: Intra-observer pearson's correlation coefficient of radiological measurements of lateral knee ligaments by Pietrini et al.[3] in antero-posterior view.

Table 32b represents the intra-observer Pearson's correlation coefficient for the radiological measurements of lateral knee ligaments by Pietrini et al.[3] in an anteroposterior view. The intra-observer Pearson's correlation coefficients for LCL and PT from the femoral condylar line are 0.986 and 0.951, respectively. For LCL from the tibial plateau line, the intra-observer Pearson's correlation coefficient is 0.973. In our study in anteroposterior view, we found a very strong positive correlation for measurements of distal fibular attachments of lateral knee ligaments using the Pietrini et al. , [3] technique.

		Intra-observer pearson's correlation coefficient (r)	Comment
LCL	**From fibular styloid apex**	0.9608	Very strong positive correlation
	From the line drawn intersecting the most anterior & proximal aspects of the fibular head	0.935	Very strong positive correlation

Table 32c: Intra-observer pearson's correlation coefficient of radiological measurements of fibular attachments of lateral collateral ligament by Pietrini et al.[3] in lateral view.

Table 32c shows the intra-observer Pearson's correlation coefficient for the radiological measurements of distal fibular attachments of the lateral collateral ligament by Pietrini et al.[3] in lateral view. For LCL, the intra-observer Pearson's correlation coefficient for the measurement from the fibular styloid apex is 0.9608 and from the line drawn intersecting the most anterior and proximal aspects of the fibular head is 0.935. Using Pietrini et al. 's [3] technique, we discovered a very strong positive correlation for measurements of distal fibular attachments of the lateral collateral ligament.

		Intra-observer pearson's correlation coefficient (r)	Comment
LCL	**X-axis**	0.998	Very strong positive correlation
	Y-axis	0.999	Very strong positive correlation
PT	**X-axis**	0.997	Very strong positive correlation
	Y-axis	0.998	Very strong positive correlation

Table 33: Intra-observer pearson's correlation coefficient of radiological measurements of lateral knee ligaments by Kremen et al. , [9]

Table 33 shows the intra-observer Pearson's correlation coefficient for the radiological measurements of lateral knee ligaments by Kremen et al.[9]. For LCL, the intra-observer Pearson's correlation coefficients are 0.998 and 0.999 along the X-axis and the Y-axis, respectively. For PT, the intra-observer Pearson's correlation coefficients are 0.997 and 0.998 along the X-axis and the Y-axis, respectively. We found a very strong positive correlation for measurements of lateral knee ligaments by the Kremen et al.[9] technique, in our study.

		Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	**X-axis**	0.995	Very strong positive correlation
	Y-axis	0.991	Very strong positive correlation
POL	**X-axis**	0.996	Very strong positive correlation
	Y-axis	0.984	Very strong positive correlation
MPFL	**X-axis**	0.995	Very strong positive correlation
	Y-axis	0.986	Very strong positive correlation

Table 34a: Intra-observer pearson's correlation coefficient of radiological measurements of medial knee ligaments by Wijdicks et al.[4] in lateral view.

Table 34a shows the intra-observer Pearson's correlation coefficient for the radiological measurements of medial knee ligaments by Wijdicks et al.[4]. The intra-observer Pearson's correlation coefficient for sMCL along the X-axis and the Y-axis is 0.995 and 0.991, respectively. For POL, the intra-observer Pearson's correlation coefficients are 0.996 and 0.984 along the X and Y axes, respectively. For MPFL, the intra-observer Pearson's correlation coefficients are 0.995 and 0.986 along the X and Y axes, respectively. We found a very strong positive correlation for measurements of medial knee ligaments using the Wijdicks et al. , 2009 [4] technique in our study.

		Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	**From the femoral condylar line**	0.978	Very strong positive correlation
	From the tibial plateau line	0.996	Very strong positive correlation
PT	**From the femoral condylar line**	0.909	Very strong positive correlation
MPFL	**From the femoral condylar line**	0.993	Very strong positive correlation

Table 34b: Intra-observer pearson's correlation coefficient of radiological measurements of medial knee ligaments by Wijdicks et al.[4] in antero-posterior view.

Table 34b represents the intra-observer Pearson's correlation coefficient for the radiological measurements of medial knee ligaments by Wijdicks et al.[4] in an anteroposterior view. The intra-observer Pearson's correlation coefficients observed for sMCL, PT, and MPFL from the femoral condylar line are 0.978, 0.909, and 0.993, and the intra-observer Pearson's correlation coefficient observed from the tibial plateau line for sMCL is 0.9996. In our study, we found a very strong positive correlation for measurements of medial knee ligaments using the Wijdicks et al. , 2009 [4] technique in the anteroposterior view.

		Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	**From medial tibial slope line**	0.991	Very strong positive correlation
	From mid-diaphyseal axis	0.991	Very strong positive correlation

Table 35: Intra-observer pearson's correlation coefficient of radiological measurements of distal tibial attachments of superficial medial collateral ligament by Wijdicks et al.[4] in lateral view.

Table 35 shows the intra-observer Pearson's correlation coefficient for the radiological measurements of distal tibial attachments of the superficial medial collateral ligament by Wijdicks et al.[4] in lateral view. From the medial tibial slope line, the intra-observer Pearson's correlation for sMCL is 0.991, and from the mid-diaphyseal axis, the intra-observer Pearson's correlation for sMCL is 0.991, and we found a very strong positive correlation for measurements of distal tibial attachments of the superficial medial collateral ligament by Wijdicks et al.[4] technique in our study.

		Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	**X-axis**	0.995	Very strong positive correlation
	Y-axis	0.991	Very strong positive correlation
POL	**X-axis**	0.996	Very strong positive correlation
	Y-axis	0.984	Very strong positive correlation

Table 36: Intra-observer pearson's correlation coefficient of radiological measurements of medial knee ligaments by KK Athwal et al.[8]

Table 36 shows the intra-observer Pearson's correlation coefficient of the radiological measurements of medial knee ligaments by KK Athwal et al.[8]. The intra-observer correlation coefficients for sMCL along the X-axis and Y-axis are 0.995 and 0.991, respectively. For POL, the intra-observer correlation coefficients are 0.996 and 0.984 along the X and Y axes, respectively, and for MPFL, they are 0.995 and 0.986 along the X and Y axes, respectively. We found a very strong positive correlation for the measurements of sMCL, POL, and MPFL along the X and Y axes in our study by KK Athwal et al. , 2020 [8] technique.

		Intra-observer pearson's correlation coefficient (r)	Comment
sMCL	**X-axis**	0.995	Very strong positive correlation
	Y-axis	0.994	Very strong positive correlation

Table 37: Intra-observer pearson's correlation coefficient of radiological measurements of superficial medial collateral ligament by Harsthorn et al.[6]

Table 37 represents the intra-observer Pearson's correlation coefficient for the radiological measurements of the superficial medial collateral ligament by Harsthorn et al.[6]. The intra-observer correlation coefficients for sMCL are 0.995 and 0.994 along the X- and Y-axes, respectively. We found a very strong positive correlation for the measurements of sMCL in our study by Hartshorn et al.[6].

INTER-OBSERVER CORRELATION COEFFICIENT FOR RADIOLOGICAL MEASUREMENT RESULTS

There was no difference in the intra-observer correlation coefficient between the first and second observation for both observers. Therefore, we only considered the first observation of both observers when calculating the inter-observer correlation coefficient.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)		**Comment**
	X-axis	**Y-axis**	
LCL	0.967	0.975	Very strong positive correlation
PT	0.991	0.984	Very strong positive correlation

Table 38a: Inter-observer (1^{st} & 2^{nd}) pearson's correlation coefficient of radiological measurements of lateral knee ligaments by Pietrini et al.[3]

Table 38a shows the inter-observer (1st and 2nd) Pearson's correlation coefficient for the radiological measurements of lateral knee ligaments by Petrini et al.[3]. In our study of the radiological measurements of lateral knee ligaments using the Petrini et al.[3] technique, we found a very strong positive correlation for LCL and PT in both the X and Y axes.

		Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	Comment
LCL	**From the femoral condylar line**	0.977	Very strong positive correlation
	From the tibial plateau line	0.979	Very strong positive correlation
PT	**From the femoral condylar line**	0.958	Very strong positive correlation

Table 38b: Inter-observer (1^{st} & 2^{nd}) pearson's correlation coefficient of radiological measurements of lateral knee ligaments by Pietrini et al.[3] in antero-posterior view.

Table 38b shows the inter-observer (1^{st} and 2^{nd}) Pearson's correlation coefficient for radiological measurements of lateral knee ligaments by Pietrini et al.[3] in an anteroposterior view. A very strong positive correlation was observed for LCL in both the measurements from the femoral condylar line and the tibial plateau line. Similarly, a very strong positive correlation was observed for PT from the femoral condylar line in our study for the radiological measurements of lateral knee ligaments by Petrini et al.[3] technique in anteroposterior view.

		Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	**Comment**
LCL	**From fibular styloid apex**	0.979	Very strong positive correlation
	From the line drawn intersecting the most anterior & proximal aspects of the fibular head	0.978	Very strong positive correlation

Table 38c: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of fibular attachments of lateral knee ligaments by Pietrini et al.[3] in lateral view.

Table 38c shows the inter-observer (1st and 2nd) Pearson's correlation coefficient for the radiological measurements of distal fibular attachments of lateral knee ligaments by Petrini et al.[3] in lateral view. A very strong positive correlation was observed for measurements of LCL from both the fibular styloid apex and the line drawn intersecting the most anterior and proximal aspects of the fibular head in our study for the radiological measurements of distal fibular attachments of lateral knee ligaments by Petrini et al.[3] technique.

	Inter-observer (1st & 2nd) pearson’s correlation coefficient (r)		Comment
	X-axis	Y-axis	
LCL	0.996	0.998	Very strong positive correlation
PT	0.990	0.990	Very strong positive correlation

Table 39: Inter-observer (1^{st} & 2^{nd}) pearson’s correlation coefficient of radiological measurements of lateral knee ligaments by Kremen et al. , [9]

Table 39 represents the inter-observer (1^{st} and 2^{nd}) Pearson’s correlation coefficient of radiological measurements of lateral knee ligaments by Kremen et al. [9]. In our study for the radiological measurements of lateral knee ligaments by Kremen et al.[9] technique, we found a very strong positive correlation for LCL and PT in both X and Y axes.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)		Comment
	X-axis	Y-axis	
sMCL	0.992	0.987	Very strong positive correlation
POL	0.989	0.989	Very strong positive correlation
MPFL	0.994	0.989	Very strong positive correlation

Table 40a: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of medial knee ligaments by Wijdicks et al.[4] in lateral view.

Table 40a shows the inter-observer (1st and 2nd) Pearson's correlation coefficient for the radiological measurements of medial knee ligaments by Wijdickes et al.[4]. In our study for the radiological measurements of medial knee ligaments by Wijdicks et al.[4] technique, we found a very strong positive correlation for sMCL, POL, and MPFL in both X and Y axes.

		Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	Comment
sMCL	**From the femoral condylar line**	0.959	Very strong positive correlation
	From the tibial plateau line	0.992	Very strong positive correlation
POL	**From the femoral condylar line**	0.981	Very strong positive correlation
MPFL	**From the femoral condylar line**	0.991	Very strong positive correlation

Table 40b: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of medial knee ligaments by Wijdicks et al.[4] in anteroposterior view.

Table 40b shows the inter-observer (1st and 2nd) Pearson's correlation coefficient for the radiological measurements of medial knee ligaments by Wijdicks et al.[4] in an anteroposterior view. A very strong positive correlation was observed for sMCL in both the measurements from the femoral condylar line and the tibial plateau line. Similarly, a very strong positive correlation was observed for POL and MPFL from the femoral condylar line in our study for the radiological measurements of lateral knee ligaments by Wijdicks et al.[4] technique in anteroposterior view.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)		**Comment**
	X-axis	**Y-axis**	
sMCL	0.992	0.987	Very strong positive correlation
POL	0.989	0.989	Very strong positive correlation

Table 41: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of medial knee ligaments by KK Athwal et al.[8]

Table 41 shows the inter-observer (1^{st} and 2^{nd}) Pearson's correlation coefficient for the radiological measurements of medial knee ligaments by KK Athwal et al.[8]. In our study for the radiological measurements of medial knee ligaments by KK Athwal et al.[8] technique, we found a very strong positive correlation for sMCL and POL in both X and Y axes.

	Inter-observer (1st & 2nd) pearson's correlation coefficient (r)		Comment
	X-axis	**Y-axis**	
sMCL	0.988	0.986	Very strong positive correlation

Table 42: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of superficial medial collateral ligament by Hartshorn et al.[6]

Table 42 shows the inter-observer (1st and 2nd) Pearson's correlation coefficient for the radiological measurements of the superficial medial collateral knee ligaments by Hartshorn et al.[6]. In our study, a very strong positive correlation was found for the sMCL in both the X and Y axes for radiological measurements of the superficial medial collateral ligament using the Hartshorn et al.[6] technique.

		Inter-observer (1st & 2nd) pearson's correlation coefficient (r)	Comment
sMCL	**From the medial tibial slope line**	0.993	Very strong positive correlation
	From the mid-disphyseal axis	0.996	Very strong positive correlation

Table 43: Inter-observer (1st & 2nd) pearson's correlation coefficient of radiological measurements of distal tibial attachments of medial knee ligaments by Wijdicks et al.[4] in lateral view.

Table 43 shows the inter-observer (1st and 2nd) Pearson's correlation coefficient of radiological measurements of distal tibial attachments of medial knee ligaments by Wijdicks et al.[4] in lateral view. In our study, a very strong positive correlation was observed for measurements of sMCL from both the medial tibial slope line and the tibial mid-diaphyseal line for radiological measurements of medial knee ligament distal tibial attachments by Wijdicks et al.[4] technique.

P-VALUE FOR RADIOLOGICAL MEASUREMENTS RESULTS

	Peitrini et al. , [3] (Mean)	Current study (Mean ± SD)	P-value by unpaired t-test	Kremen et al. , [9] (Mean±SD)	Current study (Mean ± SD)	P-value by unpaired t-test
X-axis	-0.4	-6.09±4.38	-	62±6	70.15±14.45	0.0097(Significant)
Y-axis	-11.7	-4.5±5.51	-	22±10	10.77±17.98	0.0085(Significant)

Table 44a: P-values for radiological measurements of lateral collateral ligament in lateral view.

Table 44a shows the P-values for radiological measurements of lateral collateral ligament. The results by Pietrini et al. , [3] are -0.4 and -11.7 along X axis and Y axis. In our study, we found 6.09±4.38 and -4.5±5.51 along the X and Y- axes. The mean measurements appear to be less numerically than those reported in the Pietrini et al.[3] study along the X-axis and higher numerically than those reported in the Pietrini et al.[3] study along the Y-axis, but the p-value cannot be calculated because SD was not provided in their study.

Similarly in the study done by Kremen et al.[9], the results are 62±6 and 22±10 along X axis and Y- axis respectively and in our study, we found 70.15±14.45 and 10.77±17.98 along X axis and Y- axis respectively. We found a significantly different measurement along both the axes with p-values along X and Y axes as 0.0097 and 0.0085 respectively.

	Peitrini et al.[3] (Mean)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
From the femoral condylar line	27.1	26.91± 5.64	-
From the tibial plateau line	34.7	31.15± 7.01	-

Table 44b: P-values for radiological measurements of lateral collateral ligament in anteroposterior view

The P-values for radiological assessments of the lateral collateral ligament in an anteroposterior view are displayed in Table 44b. The figures observed by Peitrini et al.[3] from the femoral condylar line and the tibial plateau line are 27.1 and 34.7, while in our analysis, we discovered 26.91±5.64 and 31.15±7.01. In terms of numbers, the mean measurements seem to be lower than those from the 2009 study by Pietrini et al.[3] P-value, however, cannot be determined because SD was not provided in their study.

	Peitrini et al. , [3] (Mean)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
From fibular styloid apex	17.6	11.29±4.70	-
From the line drawn intersecting the most anterior & proximal aspects of the fibular head	8.7	5.23±3.56	-

Table 44c: P-values for radiological measurements of fibular attachments of lateral collateral ligament in lateral view.

Table 44c shows the P-values for radiological measurements of the distal fibular attachments of the lateral collateral ligament in lateral view. For the measurements taken from the styloid apex of the fibula and the line drawn to cross the most anterior and proximal aspect of the fibular head, we got 11.29±4.70 and 5.23±3.56, respectively. For the measures taken from the fibula styloid apex and the line drawn intersecting the most anterior and proximal aspects of the fibular head, respectively, Pietrini et al.[3] reported values of 17.6 and 8.7. For the measures taken from the fibula styloid apex and from the line drawn intersecting the most anterior and proximal portions of the fibular head, the mean values appear to be lower numerically than those published in the Pietrini et al.[3] research. The p-value, however, cannot be determined because SD was not provided in their study.

	Peitrini et al.[3] (mean)	**Current study (mean ± sd)**	**P-value by unpaired t-test**	**Kremen et al.[9] (mean±sd)**	**Current study (mean ± sd)**	**P-value by unpaired t-test**
X-axis	-0.9	-5.10±5.67	-	51±7	52.47±15.70	0.66 (Non-Significant)
Y-axis	-25.8	-11.81±5.90	-	43±8	29.62±22.93	0.006 (Significant)

Table 45a: P-values for radiological measurements of popliteal tendon in lateral view.

Table 45a represents the P-values for radiological measurements of the popliteal tendon. In comparison to the study conducted by Pietrini et al.in [3] which indicated -0.9 and -25.8 along the X and Y axes, respectively, our analysis discovered -5.10±5.67 and 11.81±5.90. The mean measurements seem to be higher numerically along the Y-axis and lower numerically along the X-axis than those reported in the Pietrini et al.[3] research. However, the p-value cannot be determined because SD was not provided in their study.

When compared to Kremen et al.[9] findings of 51±7 and 43±8 along the X and Y axes, respectively, our results of 52.47±15.70 along the X-axis demonstrates a statistically non-significant different measurement with a p-value of 0.66 and 29.62±22.93 along the Y axes demonstrate a significantly different measurement with a p-value of 0.006.

	Peitrini et al.[3] (Mean)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
From the femoral condylar line	14.5	16.53±5.63	-

Table 45b: P-values for radiological measurements of popliteal tendon in anteroposterior view.

The P-values for radiological assessments of the popliteal tendon in an anteroposterior view are displayed in Table 45b. According to Peitrini et al.[3] the mean was 14.5 when calculated from the femoral condylar line, while in the present study, it was 16.53±5.63. The p-value cannot be determined because SD was not provided in their study, however, the mean measurements seem to be numerically greater than those stated in the Peitrini et al.[3] study

	Wijdicks et al. [4] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test	KK Athwal et al. [8] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test	Hartshorn et al.[6] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test
X-axis	8.6 ± 3.6	3.06±6.74	0.0186 (Significant)	10 ± 3	3.06±6.74	0.0001 (Significant)	- 1.6 ± 4.3	1.81±5.78	0.1153 (Non-Significant)
Y-axis	- 11 ± 2.3	-3.53±5.64	0.0003 (Significant)	- 2 ± 3	-3.53±5.64	0.2791 (Non-Significant)	4.9 ± 2.1	4.79±5.19	0.9517 (Non-Significant)

Table 46a: P-values for radiological measurements of superficial medial collateral ligament in lateral view.

The P-values for the radiological measures of the superficial medial collateral ligament are shown in Table 46a.

According to Wijdicks et al.[4] the findings of their investigation are 8.6±3.6 and -11±2.3 along the X and Y axes, respectively. 3.06±6.74 and -3.53±5.64 were found in our investigation, and when we compared them, we found that they were significantly different measurements with p-values of 0.0186 and 0.0003 on the X and Y axes.

The results of the study by KK Athwal et al. , 2020 [8] are 10 3 and -2 3 along the X and Y axes, respectively. In contrast, we discovered 3.06±6.74 and -3.53±5.64 along both axes in our investigation. With a p-value of 0.0001, we observed significantly different measurements along the X-axis, and with a p-value of 0.2791, we observed significantly different measurements along the Y-axis.

1.6±4.3 and 4.9±2.1 in the X and Y axes, respectively, were the results of the study by Hartshorn et al.from 2013 [6], however, in our study, those values were 1.81±5.78 and 4.79±5.19. After comparison, we couldn't really observe any measures that were significantly different, with p values of 0.1153 and 0.9517 along the X and Y axes, respectively.

	Wijdicks et al.[4] (Mean ± SD)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
From the femoral condylar line	30.5±2.4	27.27±5.23	0.0661 (Non-Significant)
From the tibial plateau line	60.1±5.5	72.09±14.20	0.0128 (Significant)

Table 46b: P-values for radiological measurements of superficial medial collateral ligament in anteroposterior view.

Table 46b shows the P-values for radiological measurements of the superficial medial collateral ligament in an anteroposterior view. The measurements observed by Wijdicks et al.[4] are 30.5±2.4 and 60.1±5.5 from the femoral condyle line and tibial plateau line, respectively, and in our study, we found 27.27±5.23 and 72.09±14.20, respectively. We found statistically non-significant different measurements with p values of 0.0661 from the femoral condylar line and significantly different measurements with p values of 0.0128 from the tibial plateau line.

	Wijdicks et al.[4] (Mean)	Current study (Mean ± SD)	P-value by unpaired t-test
From medial tibial slope line	66.1±3.6	66.87±16.06	0.8772 (Non-Significant)
From mid-diaphyseal axis	- 11.8±3.2	-1.78±4.60	0.0001 (Significant)

Table 46c: P-values for radiological measurements of distal tibial attachments of superficial medial collateral ligament in lateral view.

The P-value for radiological measures of the superficial medial collateral ligament's distal tibial attachments in lateral view is displayed in Table 46c. The mid-diaphyseal axis and the medial tibial slope line yielded readings of 66.8716.06 and -1.784.60, respectively. According to Wijdicks et al.[4] the mid-diaphyseal axis and the medial tibial slope line, respectively, show findings of 66.13.6 and -11.83.2. For measurements taken from the medial tibial slope line, we discovered statistically non-significant difference findings with p-value of 0.8772, while for measurements taken from the mid-diaphyseal axis, we found very significant difference results with p-value of 0.0001

	Wijdicks et al.[4] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test	KK Athwal et al.[8] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test
X-axis	- 2.4 ± 4.4	-3.52±9.23	0.7105 (Non-Significant)	- 5 ± 4	-3.52±9.23	0.501 (Non-Significant)
Y-axis	- 5.6 ± 2.8	-4.09±4.16	0.3004 (Non-Significant)	1 ± 4	-4.09±4.16	0.0003 (Significant)

Table 47a: P-values for radiological measurements of posterior oblique ligament in lateral view.

The posterior oblique ligament P-values for radiological measures are displayed in Table 47a. According to Wijdicks et al.[4] findings along the x-axis and Y-axis are 2.4±4.4 and 5.6±2.8, but in our investigation, we discovered -3.52±9.23 and -4.09±4.16. With p values of 0.7105 and 0.3004 along both axes, the comparison revealed statistically non-significant differences in the measurements.

In the study by KK Athwal et al. , 2020 [8], the X-axis and Y-axis values were determined to be -5±4 and 1±4, respectively; however, in our investigation, we discovered -3.52±9.23 and -4.09±4.16. Following the comparison, we discovered that measurements along the X-axis were significantly different from those along the Y-axis, with a p-value of 0.0003 and 0.501, respectively.

	Wijdicks et al.[4] (Mean ± SD)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
From the femoral condylar line	34.8±2.7	28.88±5.86	0.0042 (Significant)

Table 47b: P-values for radiological measurements of posterior oblique ligament in anteroposterior view

The P-values for radiological assessments of the posterior oblique ligament in anteroposterior view are shown in Table 47b. Our study recorded 28.88±5.86 from the femoral condylar line, whereas Wijdickes et al.[4] measured 34.8±2.7. When comparing, we discovered a measurement difference that was extremely significant (P = 0.0042).

	Wijdicks et al.[4] (Mean ± SD)	**Current study (Mean ± SD)**	**P-value by unpaired t-test**
X-axis	8.8 ± 5.3	6.02±7.17	0.277(Non-Significant)
Y-axis	2.6 ± 2.1	0.52±4.42	0.1571(Non-Significant)

Table 48a: P-values for radiological measurements of medial patellofemoral ligament in lateral view.

The P-value for radiological assessments of the medial patellofemoral ligament is shown in Table 48a. Wijidicks et al.[4] discovered 8.8±5.3 and 2.6±2.1 measurements along the X and Y axes, respectively, whereas we found 6.02±7.17 and 0.52±4.42 measurements along the X and Y axes, respectively. When the measurements along the X and Y axes are compared, there is no significant difference with P-values of 0.277 and 0.1571. We found no statistically significant differences in medial patellofemoral ligament measures along either axis.

	Wijdicks et al.[4] (Mean ± SD)	Current study (Mean ± SD)	P-value by unpaired t-test
From the femoral condylar line	42.3±2.1	31.46±9.68	0.0012 (Significant)

Table 48b: P-values for radiological measurements of medial patellofemoral ligament in anteroposterior view.

The P-value for anteroposterior radiological assessments of a medial patellofemoral ligament is shown in Table 48b. In contrast to our present research's mean and SD results of 31.46±9.68, Wijdicks et al. 's [4] study revealed mean and SD values of 42.3±2.1 from the femoral condylar line. After comparison, we discovered extremely significant differences in the measurements with p-values of 0.0012.

SUMMARY OF RESULTS

LATERAL COLLATERAL LIGAMENT (LCL)

Lateral view:

1. **Peitrini et al.[3]:** Qualitatively, the femoral attachment of the lateral collateral ligament was located in the *posterodistal quadrant*. Quantitatively, it was 7.52±1.09 mm (Max=9.75, Min=5.89) from the lateral epicondyle. With regard to the osseous reference lines, it was 4.5±5.51 mm (Max=6.3, Min=-12.8) posterior to the posterior femoral cortex extension line (Y-axis) and 6.09±4.38 mm (Max=-1.06, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Regarding the distal fibular attachments of the lateral collateral ligament with osseous reference line on the fibula, it was located at a distance of 11.29±4.70 mm (Max=19.5 Min=4.62) distally from the fibular styloid apex and 5.23±3.56 mm (Max=13 Min=0.53) distally from the line drawn intersecting the most anterior and proximal aspects of the fibular head.

2. **Kremen et al.[9]:** With regard to osseous reference lines, it was estimated to be 70.15±14.45% (Max=91.3, Min=48.3) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 10.77±17.98% (Max=35.5, Min=-17.2) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction

Anteroposterior view:

1. **Peitrini et al.[3]:** The lateral collateral ligament was located 26.91±5.64 mm (Max=35.4, Min=16) proximal to the femoral condylar line and 31.15±7.01 mm (Max=40.5, Min=16) distal to the tibial plateau line.

- **POPLITEUS TENDON (PT)**

Lateral view:

1. **Peitrini et al.[3]:** Qualitatively, the femoral attachment of the Popliteal tendon was located in the posterodistal quadrant. Quantitatively, it was 9.02±2.49 mm

(Max=16.1, Min=5.66) from the lateral epicondyle. With regard to the osseous reference lines, it was 11.81±5.90 mm (Max=0.8, Min=-20.2) posterior to the posterior femoral cortex extension line (Y-axis) and 5.10±5.67 mm (Max=5.33, Min=-13.7) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

2. **Kremen et al.[9]:** With regard to osseous reference lines, it was estimated to be 52.47±15.70% (Max=84.3, Min=31.8) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 29.62±22.93% (Max=79.1, Min=-14.4) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction.

Anteroposterior view:

1. **Peitrini et al.[3]:** The popliteal tendon was located 16.53±5.63 mm (Max=29.5, Min=10.4) proximal to the femoral condylar line.

- **SUPERFICIAL MEDIAL COLLATERAL LIGAMENT (sMCL)**

Lateral view:

1. **Wijdicks et al.[4]:** Qualitatively, the femoral attachment of the Superficial medial collateral ligament was located in the Anterodistal quadrant. Quantitatively, it was 7.37± 1.44mm (Max= 10.1, Min= 4.57) from the medial epicondyle. With regard to the osseous reference lines, it was 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm (Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Regarding the distal tibial attachments of the Superficial medial collateral ligament with osseous reference line on the tibia, it was located at a distance of 66.87±16.06 mm (Max=98.9 Min=44.3) distally from the medial tibial slope line and 1.78±4.60 mm (Max=6.94 min=-7.65) posteriorly from the mid diaphyseal axis of the tibia.

2. **KK Athwal et al.[8]:** With regard to the osseous reference lines, it was 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm (Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

3. **Hartshorn et al.[6]:** Qualitatively, the femoral attachment of the Superficial medial collateral ligament was located in the Anteroproximal quadrant. With regard to the osseous reference lines, it was 4.79± 5.19mm (Max= 13.44, Min=-5.41) anterior to the posterior femoral cortex extension line (Y-axis) and 1.81± 5.78mm (Max= 9.9, Min=-6.69) proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

1. **Wijdicks et al.[4]:** The Superficial medial collateral ligament was located at 27.27± 5.23 mm (Max= 36.6, Min= 19) proximal to the femoral condylar line and 72.09± 14.20 mm (Max= 99.1, Min= 52.6) distal to the tibial plateau line.

- **POSTERIOR OBLIQUE LIGAMENT (POL)**

Lateral view:

1. **Wijdicks et al.[4]:** Qualitatively, the femoral attachment of the Posterior oblique ligament was located in the Posterodistal quadrant. Quantitatively, it was 12.9±3.37 mm (Max= 16.6, Min= 6.2) from the medial epicondyle. With regard to the osseous reference lines, it was 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

2. **KK Athwal et al.[8] :** With regard to the osseous reference lines, it was 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

1. **Wijdicks et al.[4]:** The Posterior oblique ligament was located at 28± 5.8 mm (Max= 40.1, Min= 20.9) proximal to the femoral condylar line.

- **MEDIAL PATELLOFEMORAL LIGAMENT (MPFL)**

Lateral view:

1. **Wijdicks et al.[4]:** Qualitatively, the femoral attachment of the Medial patellofemoral ligament was located in the Anteroproximal quadrant. Quantitatively, it was 7.34± 2.06 mm (Max= 11, Min= 3.97) from the medial epicondyle. With regard to the osseous reference lines, it was 0.52± 4.42 mm (Max= 5.66, Min=-9.4) anterior to the posterior femoral cortex extension line (Y-axis) and 6.02± 7.17 mm (Max= 15.7, Min=-7.06) proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis).

Anteroposterior view:

1. **Wijdicks et al.[4]:** The Medial patellofemoral ligament was located at 31.46±9.68 mm (Max= 52.1, Min= 14.5) proximal to the femoral condylar line.

DISCUSSION

The purpose of this study is to examine the anatomical attachments of medial and lateral knee ligaments in Our study. The goal was to compare the anatomical attachments of ligaments of the knee with radiographic locations obtained by various published methods and to assess the Inter-observer and Intra-observer correlation of radiographic methods for assessing the ligament attachments. This information is helpful while repairing and reconstructing knee ligaments.

There are several measurement techniques described for the reconstruction of knee ligaments. All of these measurement techniques depend on the appropriate identification of specific femoral, tibial and fibular attachment sites to restore the native anatomy and function of the joint. The literature provides numerous qualitative and quantitative gross anatomic descriptions of these medial and lateral knee ligamentous structures; however, variations are observed among these studies regarding the exact ligament attachments.

Anatomical localization of ligaments is essential during surgical reconstruction for best outcomes in ligament injuries. Non-anatomic reconstruction leads to inferior outcomes. Accurate radiographic landmarks also help in the postoperative evaluation of tunnels for accuracy. Hence there is a need for an accurate radiographic method that can reliably predict the anatomical location of the ligaments during surgical reconstruction.

Very few cadaveric studies (1-5,7,16-18,20,21) have been done to assess the exact anatomical insertion of knee ligaments. However, those studies don’t agree completely on the exact location of knee ligament insertions. All the studies have been done on the cadavers of the American / European population origin, none representing the Asian / Indian population. As there are anatomical structural differences in various population cohorts, hence it becomes crucial to perform a study on the Indian knees and it serves better if the surgeon has data derived from the same population cohort as the patient.

Multiple radiographic methods have been described to know the ligament attachments on the femur and tibia to be used during ligament reconstruction surgery (3,4,6-17). There are variations in those methods also, and it is unclear whether they represent the actual anatomical attachment of knee ligaments.

We understand that it can be difficult to apply quantitative measurements from a study to all knees due to the trained observer's clinical limitations when it comes to precisely locating attachment sites - this is especially true in cases of chronic injuries or revision surgeries. To address this, we have provided qualitative and quantitative descriptions of the medial and lateral knee ligament attachment sites.

LATERAL COLLATERAL LIGAMENT (LCL)

The femoral origin of the LCL in our study was found at a distance of 6.25±2.36 mm (Max=1.62 Min=-8.61) posterior (X-axis) and 1.55±3.40 mm (Max=8.06 Min=-7.52) proximal (Y-axis) to the lateral epicondyle (Mid-point 0,0).

Using the Pietrini et al.[3] measurement technique, in the current study, the *femoral attachment of the lateral collateral ligament was located in the posterodistal quadrant qualitatively*, the same as in their study.

Quantitatively, it was located at 7.52±1.09 mm (Max=9.75, Min=5.89) from the lateral epicondyle in the current study. In contrast, in the study by Pietrini et al.[3], it was located at a distance of 4.3 mm from the lateral epicondyle. *Numerically, the mean LCL measurement appears to be higher than those reported by Pietrini et al* [3]. However, the p-value cannot be calculated because SD was not provided in their study.

With regard to the osseous reference lines in Our study, it was located at 4.5±5.51 mm (Max=6.3, Min=-12.8) posterior to the posterior femoral cortex extension line (Y-axis) and 6.09±4.38 mm (Max=-1.06, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Whereas, in the actual study conducted by Pietrini et al.[3], it was located at 0.4 mm posterior to the posterior extension line and 11.7 mm distal to the line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. The *mean measurements appear to be less numerically* *than those reported in the Pietrini et al.study along the X-axis and higher along the Y-axis.*

Regarding the fibular attachments of the lateral collateral ligament with osseous reference line on the fibula in Our study, it was located at a distance of 11.29±4.70 mm (Max=19.5 Min=4.62) distally from the fibular styloid apex and 5.23±3.56 mm (Max=13 Min=0.53) distally from the line drawn intersecting the most anterior and proximal aspects of the fibular head. In contrast, in the actual study conducted by Pietrini et al.[4], it was located at 17.6 mm distal to the fibular styloid apex and 8.7 mm distal to the line drawn intersecting the most anterior and proximal aspects of the fibular head. The mean values appear to be lower numerically than those published in the Pietrini et al.[4] research.

The lateral collateral ligament in AP views in Our study, located at 26.91±5.64 mm (Max=35.4, Min=16) proximal to the femoral condylar line and 31.15±7.01 mm (Max=40.5, Min=16) distal to the tibial plateau line. In contrast, in the study conducted by Pietrini et al. , it was located at 27.1 mm proximal to the femoral condylar line and 34.7 distal to the tibial plateau line. In terms of numbers, the mean measurements seem to be lower than those from the 2009 study by Pietrini et al [3].

Using the Kremen et al.[9] measurement technique, in the current study, the femoral attachment of the lateral collateral ligament was situated at 70.15±14.45% (Max=91.3, Min=48.3) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 10.77±17.98% (Max=35.5, Min=-17.2) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction. In the study conducted by Kremen et al.[9], in their study reported it to be 62±6% of the distance along the blumensaat line in the anterior-posterior direction and 22±10% of the distance along the distal extent of the perpendicular bisector of the blumensaat line in the proximal-distal direction. And we found this a significantly different measurement along both axes with p-values along the X and Y axes as 0.0097 and 0.0085, respectively.

POPLITEAL TENDON (PT)

The femoral origin of the PT in the current study on Indian cadaveric knees was found at a distance of 5.46±3.08 mm (Max=-1.75 Min=-13.3) posterior (X-axis) and 6.36±2.89 mm (Max=-1.34 Min= -11.5) distal (Y-axis) to the lateral epicondyle (Mid-point 0,0).

Using the Pietrini et al.[3] measurement technique, in the current study, the femoral attachment of the Popliteal tendon in Our study was located in the posterodistal quadrant, the same as in their original study.

Quantitatively in Our study, it was located at a distance of 9.02±2.49 mm (Max=16.1, Min=5.66) from the lateral epicondyle. In contrast, in the actual study done by Pietrini et al. , it was located at a distance of 12.2 mm from the lateral epicondyle. Numerically, the mean PT measurement appears to be higher than those reported by Pietrini et al.[3]. (The p-value cannot be determined because SD was not provided in their study.)

With regard to the osseous reference lines in Our study, it was located at a distance of 11.81±5.90 mm (Max=0.8, Min=-20.2) posterior to the posterior femoral cortex extension line (Y-axis) and 5.10±5.67 mm (Max=5.33, Min=-13.7) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). In contrast, in the actual study done by Pietrini et al.[3], it was located at 0.9 mm posterior to the posterior femoral cortex extension line and 25.8 mm distal to the line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. The mean measurements seem to be higher numerically along the Y-axis and lower numerically along the X-axis than those reported in the Pietrini et al.[3] research. (The p-value cannot be determined because SD was not provided in their study.)

The popliteal tendon in the AP view in Our study was located at a distance of 16.53±5.63 mm (Max=29.5, Min=10.4) proximal to the femoral condylar line. In contrast, in the actual study done by Pietrini et al.[3], it was located at a distance of 14.5 mm proximal to the femoral condylar line. The p-value cannot be determined because

SD was not provided in their study, however, the mean measurements seem to be numerically greater than those stated in the Pietrini et al.[3] study.

Using the Kremen et al.[9] measurement technique, in the current study, the femoral attachment of the popliteal tendon in Our study was estimated to be 52.47±15.70% (Max=84.3, Min=31.8) of the distance along the blumensaat line (x-axis) in the anterior-posterior direction and 29.62±22.93% (Max=79.1, Min=-14.4) of the distance along the distal extent of the perpendicular bisector of the blumensaat line (Y-axis) in the proximal-distal direction. In contrast, in their original study by Kremen et al.[9], reported it to be 51±7% of the distance along the blumensaat line in the anterior-posterior direction and 43±8% of the distance along the distal extent of the perpendicular bisector of the blumensaat line in the proximal-distal direction. And we observed a statistically non-significant different measurement with a p-value of 0.66 along the X-axis and a significantly different measurement with a p-value of 0.006 along the Y-axis.

SUPERFICIAL MEDIAL COLLATERAL LIGAMENT (sMCL)

The femoral origin of the sMCL in Our study was found at a distance of 4.36±3.62 mm (Max=1.79 Min=-8.16) posterior (X-axis) and 0.25±5.08 mm (Max=6.6 Min=-7.2) proximal (Y-axis) to the medial epicondyle (Mid-point 0,0).

Using the Wijdicks et al.measurement technique [4], in the current study, the femoral attachment of the superficial medial collateral ligament in our study was located in the Anterodistal quadrant, the same as in the study conducted by Wijdicks et al.[4].

Quantitatively in our study, it was located at a distance of 7.37± 1.44mm (Max= 10.1, Min= 4.57) from the medial epicondyle. In contrast, in the study by Wijdicks et al.[4], it was located at a distance of 6.0±0.8 mm from the medial epicondyle. And we have observed a highly significant difference in the measurements of sMCL with a p-value of 0.0075 compared to Wijdicks et al.[4].

With regard to the osseous reference lines in Our study, it was 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm (Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). In contrast, Wijdicks et al. , it was located at a distance of 8.6±3.6 mm anterior to the posterior femoral cortex extension line and 11.0±2.3 mm distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. We found that they were significantly different with p-values of 0.0186 and 0.0003 on the X and Y axes respectively when compared to Wijdicks et al.[4] study.

Regarding the distal tibial attachments of the sMCLwith osseous reference line on the tibia in Our study, it was located at a distance of 66.87±16.06 mm (Max=98.9 Min=44.3) distally from the medial tibial articular margin and 1.78±4.60 mm (Max=6.94 min=-7.65) posteriorly from the mid diaphyseal axis of the tibia. In contrast, in the study by Wijdicks et al.[4], it was located at a distance of 66.1±3.6 mm distally from the medial tibial articular margin and 11.8±3.2 mm posteriorly from the mid diaphyseal axis of the tibia. For measurements taken from the medial tibial articular margin, we discovered statistically non-significant different measurements with a p-value of 0.8772, while for measurements taken from the mid-diaphyseal axis, we found very significant different measurements with a p-value of 0.0001, when compared to Wijdicks et al.[4].

The sMCL attachments in Indian cadaveric knees were located at 27.27± 5.23 mm (Max= 36.6, Min= 19) proximal to the femoral condylar line and 72.09± 14.20 mm (Max= 99.1, Min= 52.6) distal to the tibial plateau line. In contrast, in the actual study conducted by Wijdicks et al.[4], it was located at a distance of 30.5±2.4 mm proximal to the femoral condylar line and 60.1±5.5 mm distal to the tibial plateau line. And we found a statistically non-significant different measurement with p values of 0.0661 from the femoral condylar line and significantly different measurements with p values of 0.0128 from the tibial plateau line compared to the actual study conducted by Wijdicks et al.[4].

Using the KK Athwal et al.[8] measurement technique, in our study, the sMCL was quantitatively located at a distance of 3.53±5.64 mm (Max= 11.7, Min=-15.1) anterior to the posterior femoral cortex extension line (Y-axis) and 3.06±6.74mm

(Max=6.55, Min=-15.4) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Whereas in their study KK Athwal et al.[8], reported it to be located at a distance of 10±3 mm anterior to the posterior femoral cortex extension line and 2±3 mm distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. With a p-value of 0.0001, we observed significantly different measurements along the X-axis. With a p-value of 0.2791, we observed non-significant different measurements along the Y-axis, when compared to the KK Athwal et al.[8] study results.

Applying the Hartshorn et al.[6] measurement technique, the femoral attachment of the superficial medial collateral ligament in our study was located in the anteroproximal quadrant qualitatively. In contrast, in the study by Hartshorn et al.[6], it was located in the posteroproximal quadrant.

With regard to the osseous reference lines in the current study, sMCL was located at 4.79± 5.19mm (Max= 13.44, Min=-5.41) anterior to the posterior femoral cortex extension line (Y-axis) and 1.81± 5.78mm (Max= 9.9, Min=-6.69) proximal to the reference line perpendicular to the posterior femoral cortex, where it intersecting the blumensaat line (X-axis). In contrast, in the study by Hartshorn et al.[6], it was located at a distance of 1.6±4.3 mm posterior to the posterior femoral cortex extension line and 4.9±2.1 mm proximal to the reference line perpendicular to the posterior femoral cortex, where it intersects the blumensaat line. After comparison, we couldn't really observe any measures that were significantly different, with p values of 0.1153 and 0.9517 along the X and Y axes, respectively, when compared to the study by Hartshorn et al.[6].

POSTERIOR OBLIQUE LIGAMENT (POL)

The femoral origin of the POL in our study was found at a distance of 11.50±4.42 mm (Max=-1.42 Min=-16.6) posterior (X-axis) and 0.49±5.18 mm (Max=9.36 Min=-9.35) distal (Y-axis) to the medial epicondyle (Mid-point 0,0).

Applying the Wijdicks et al.[4] measurement technique in the current study, the femoral attachment of the POL in Our study was located in the posterodistal quadrant, the same as reported by Wijdicks et al.[4].

Quantitatively in the current study, POL was located at a distance of 12.9±3.37 mm (Max= 16.6, Min= 6.2) from the medial epicondyle. In contrast, in the actual study done by Wijdicks et al.[4], it was located at a distance of 18.1±2.8 mm from the medial epicondyle. And we have observed a highly significant difference in the measurements of POL with a p-value of 0.0002 compared to Wijdicks et al.[4].

With regard to the osseous reference lines in the current study, POL was 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). In the study by Wijdicks et al.[4], it was located at 2.4±4.4 mm posterior to posterior femoral cortex extension line and 5.6±2.8 mm distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. With p values of 0.7105 and 0.3004 along both axes, the comparison revealed statistically non-significant differences in the measurements compared to the results of Wijdicks et al.[4].

The POL in Our study was located at 28± 5.8 mm (Max= 40.1, Min= 20.9) proximal to the femoral condylar line. Wijdicks et al.[4] reported it at a distance of 34.8±2.7 mm proximal to the femoral condylar line. When comparing with the study by Wijdicks et al.[4], we observed a different measurement that was extremely significant with a p-value of 0.0042.

Using the KK Athwal et al.(2020) [8] measurement technique, POL insertion in the current study was located at 4.09±4.16 mm (Max= 3.61, Min=-11.5) posterior to the posterior femoral cortex extension line (Y-axis) and 3.52±9.23mm (Max=18.9, Min=-15.2) distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Whereas, KK Athwal et al.[8] reported it to be located at 5±4 mm posterior to the posterior femoral cortex extension line and 1±4 mm proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. On comparing our results, those of KK Athwal et al.[8], we observed that measurements along the X-axis were significantly different from those along the Y-axis, with a p-value of 0.0003 and 0.501, respectively.

MEDIAL PATELLOFEMORAL LIGAMENT (MPFL)

The femoral origin of the MPFL in our study was found at a distance of 1.18±5.47 mm (Max=7.36 Min=-8.93) anterior (X-axis) and 2.70±4.68 mm (Max=10.9 Min=-7.03) proximal (Y-axis) to the medial epicondyle (Mid-point 0,0).

Applying the Wijdicks et al.[4] measurement technique in our cadavers, the femoral attachment of the MPFL was located in the antero-proximal quadrant, the same as in the original study by Wijdicks et al.[4].

Quantitatively, it was located at a distance of 7.34± 2.06 mm (Max= 11, Min= 3.97) from the medial epicondyle. Wijdicks et al.[4] reported it at a distance of 15.9±3.2 mm from the medial epicondyle. There was a highly significant difference in the measurements of MPFL with a p-value of 0.0001 compared to Wijdicks et al.[4].

With regard to the osseous reference lines, MPFL insertion in the current study was 0.52± 4.42 mm (Max= 5.66, Min=-9.4) anterior to the posterior femoral cortex extension line (Y-axis) and 6.02± 7.17 mm (Max= 15.7, Min=-7.06) proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line (X-axis). Wijdicks et al.[4] reported 8.8±5.3 mm anterior to the posterior femoral cortex extension line and 2.6±2.1 mm proximal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the blumensaat line. When the measurements along the X and Y axes are compared with the results of Wijdicks et al.[4], although there were no statistically significant differences in MPFL measurements along either axis with P-values of 0.277 and 0.1571 respectively, our study found insertion more proximally located and less anterior.

In our study, MPFL was located at 31.46±9.68 mm (Max= 52.1, Min= 14.5) proximal to the femoral condylar line. In contrast, in the actual study done by Wijdicks et al.[4], it was located at 42.3±2.1 mm proximal to the femoral condylar line. On comparing with the results of Wijdicks et al.[4], we observed extremely significant differences in the measurements with a P-value of 0.0012.

CONCLUSION

Our study on Indian cadaveric knees brings forward the exact location of the medial and lateral ligament attachments, which is very crucial information for any surgeon operating on a patient in a similar population.

On comparing our data with the previously published studies, variations were noticed in ligament insertion points for some ligaments, these variations were significant, which might urge the surgeon to rethink their ligament reconstruction strategy while operating for ligament injuries. This difference also points towards possible demographic variations in the anatomy of knee ligaments, which have not been discussed earlier in the literature.

This is the first study done on cadavers of Indian/Asian origin to evaluate ligament insertions and also the first to provide a comparison with previously published literature.

Our study has assessed the published radiographic methods for the localization of knee ligaments and compared the cadaveric attachments with their derived points of attachments, we have noticed that none of the methods accurately depicts the exact attachment point of any ligament.

Our study has limitations too, the small number of cadavers studied is one of them. The age of cadavers was >65 years (mean; 79.7 years), this is higher than the usual patients of ligament reconstruction; hence there might be some age-related changes in anatomy leading to variations in results. But being a cadaveric study, age is always going to be high in such studies.

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