# ANTHROPOMETRIC ANALYSIS OF DISTAL FEMUR BETWEEN BOTH KNEES IN SOUTH INDIAN POPULATION USING DIGITAL XRAYS

**Dissertation submitted in Partial fulfilment of the**

**regulations required for the award of**

**M.S. Degree in Orthopaedics**

**THE TAMIL NADU Dr M.G.R. MEDICAL UNIVERSITY**

**CHENNAI, TAMIL NADU**

**May 2019**

# CERTIFICATE

This is to certify that this dissertation titled "**Anthropometric analysis of distal femur between both knees in South Indian population using digital Xrays**" is a bonafide work done by **Dr.Pon Sen Surya**,post graduate student of Coimbatore medical college hospital. This dissertation has been prepared by **Dr.Pon Sen Surya** under my direct guidance and supervision to my satisfaction in partial fulfillment of **Dr.M.G.R.Medical University**, regulations for the award of **M.S.Degree in Orthopaedics**.

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Variations in the anatomy of knee are well described, however the true incidence of

anthropometric differences that occur between the two knees is rarely described. Such difference when it exists will result in an erroneous result while doing bilateral Total Knee Arthroplasty(TKA) by using the pre-operative data of a single knee. In our study we will review the literature about the existence of such differences, the methods to find the differences and the implications of such differences in TKA.

In the study by Venkata Gurava Reddy et al[1], they

did a retrospective analysis of 289 patients who underwent bilateral TKA with the hypothesis that both sides in these patients may not be symmetrical in all. They analyzed the incidence of asymmetry of femoral and tibial components among bilateral knee arthroplasty cases and evaluated the outcome of those cases.

They concluded

that the incidence of asymmetry of components in bilateral TKA is around 9% and hence recommended that each knee must be sized independently, and solely relying on the contralateral knee measurements might lead to improper implantation.

The gold standard for measuring knee alignment is with weight-bearing full-limb radiographs, allowing calculation of the mechanical axis of the lower limb. This investigation is not routinely performed on patients in the clinical setting, and results in greater cost and inconvenience. Full limb radiographs involve exposure of the pelvis to radiation, with effective radiation from one film at 73-fold higher than an AP knee radiograph . In this study by Colebatch et al[2], suggests that AP knee radiographs may be used for measuring knee alignment by anatomical axis, which are safer and more readily available in clinical practice.

Knee alignment was measured in 40 subjects (80 knees) from the twinsuk registry. Measurement of mechanical knee alignment was from

Full Limb Radiographs(

FLR) and anatomic knee alignment from weight-bearing AP knee radiographs. Reproducibility

of knee alignment for both methods was good.

The mean alignment angle on FLR was 178.9° (SD 2.1, range 173–183°), and 179.0° (SD 2.1, range 173–185°) on AP films. 58.8% of knees on FLR and 66.3% on AP films were of varus alignment. Good correlations were seen between results for FLR and AP radiographs.

This is the first study to assess the validity of a standard AP film for measuring knee alignment in patients without OA. The method for measuring knee alignment from AP knee radiographs is much less time consuming compared with the time taken to read full-limb radiographs, which is of benefit both in clinical and research settings. This is of particular importance as many of the existing large population cohort studies, which involve patients with normal knees and those with a background of OA, have examined knee OA using AP knee radiographs.
This data would suggest that the AP technique used would be useful for

# CERTIFICATE – II

This is to certify that this dissertation work titled …"**Anthropometric analysis of distal femur between both knees in South Indian population using digital Xrays**" of the candidate **Dr.Pon Sen Surya** with registration Number **221612253** for the award of **M.S. Degree** in the branch of **Orthopaedics** . I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **6 (six)** percentage of plagiarism in the dissertation.

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# DECLARATION

I declare that this dissertation titled **"Anthropometric analysis of distal femur between both knees in South Indian population using digital xrays"** has been prepared by me at the Coimbatore Medical College Hospital under the guidance of **Prof& HOD Dr.S.Vetrivel Chezian**, Coimbatore Medical College Hospital, Coimbatore, in partial fulfilment of Dr.M.G.R.Tamilnadu Medical University regulations for the reward of M.S.Degree in Orthopaedics.

I have not submitted this dissertation to any other university for the reward of any Degree or Diploma previously.

Place: **Dr.Pon Sen Surya**,

Date: Postgraduate in orthopaedics

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# ACKNOWLEDGEMENT

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I also thank all the postgraduates,staffs and other members of Department of Orthopaedics of Coimbatore Medical College for their help. Lastly me sincere thanks to all my beloved patients and their relatives,with their excellent co operation became the backbone of this dissertation.

**Dr.Pon Sen Surya,**

**M.S.Ortho Post Graduate.**

# CONTENTS

# INTRODUCTION

Side to side comparison of the anatomical or functional parameters in the evaluation of unilateral pathologies of the human knee joint is common practice, although the amount of asymmetry is unknown. This comparison also holds true in choosing implants to the contralateral knee in case of bilateral Total Knee Arthroplasty (TKA) when it is performed simultaneously.

Joint replacement surgery is designed to expand the envelope of function of symptomatic arthritic knees as safely and predictably as possible. Properly utilized, total knee replacement surgery is capable of substantial increases in the functional capacity of a given arthritic joint, but it is not designed to restore the full physiological function of a normal, uninjured adult knee. Future developments in the therapeutic management of arthritic knees may eventually involve biological approaches that could result in further improvements in maximizing the post-treatment envelope of function over what can be achieved with the current technique of using artificial components. By tracking the loss of osseous homeostasis in knees starting at a time prior to the development of overt radiographically identifiable degenerative changes, an improved understanding of the natural history of arthrosis could be achieved. Such an improved understanding of the natural history of knee arthrosis could have broad implications for the early detection, control, and ultimately prevention of arthrosis in all joints.

Pre-operative component sizing requires Computerised Tomogram(CT) evaluation which is very accurate. But CT results in a high radiation exposure to the patient and in case of bilateral TKA, if individual knee are evaluated then there is even higher exposure. Moreover considering the cost of CT,it is not easily affordable to the masses.

In this study we have made a novel attempt to identify the anthropometric differences that exists between the two knees of an individual using digital X-rays in the South Indian population. Thus the radiation exposure to the individual is greatly reduced and the cost is considerably lowered. Moreover the X-rays are available even in tertiary care centres and hence is easily available even in small towns. The position for filming the X-rays and the method of measuring the anthropometric parameters are all standardized so that they have good intra and inter observer reliability and reproducibility.

# AIM AND OBJECTIVES

- To evaluate the differences in the morphometric distal femur dimensions between the right and left side of a human subject.

- To improvise the measurements to the dimensions of the current Total Knee Arthroplasty(TKA)prosthetic system.

- To measure the distal femur anthropometric parameters using digital Xrays instead of a Computed Tomogram.

# REVIEW OF LITERATURE

Variations in the anatomy of knee are well described, however the true incidence of anthropometric differences that occur between the two knees is rarely described. Such difference when it exists will result in an erroneous result while doing bilateral Total Knee Arthroplasty(TKA) by using the pre-operative data of a single knee. In our study we will review the literature about the existence of such differences, the methods to find the differences and the implications of such differences in TKA.

In the study by **Venkata Gurava Reddy et al**[1], they did a retrospective analysis of 289 patients who underwent bilateral TKA with the hypothesis that both sides in these patients may not be symmetrical in all. They analyzed the incidence of asymmetry of femoral and tibial components among bilateral knee arthroplasty cases and evaluated the outcome of those cases. They concluded that the incidence of asymmetry of components in bilateral TKA is around 9% and hence recommended that each knee must be sized independently, and solely relying on the contralateral knee measurements might lead to improper implantation.

The gold standard for measuring knee alignment is with weight-bearing full-limb radiographs, allowing calculation of the mechanical axis of the lower limb. This investigation is not routinely performed on patients in the clinical setting, and results in greater cost and inconvenience. Full limb radiographs involve exposure of the pelvis to radiation, with effective radiation from one film at 73-fold higher than an AP knee radiograph . In this study by **Colebatch et al**[2], suggests that AP knee radiographs may be used for measuring knee alignment by anatomical axis, which are safer and more readily available in clinical practice. Knee alignment was measured in 40 subjects (80 knees) from the twinsuk registry. Measurement of mechanical knee alignment was from Full Limb Radiographs(FLR) and anatomic knee alignment from weight-bearing AP knee radiographs. Reproducibility of knee alignment for both methods was good. The mean alignment angle on FLR was 178.9° (SD 2.1, range 173–183°), and 179.0° (SD 2.1, range 173–185°) on AP films. 58.8% of knees on FLR and 66.3% on AP films were of varus alignment. Good correlations were seen between results for FLR and AP radiographs. This is the first study to assess the validity of a standard AP film for measuring knee alignment in patients without OA. The method for measuring knee alignment from AP knee radiographs is much less time consuming compared with the time taken to read full-limb radiographs, which is of benefit both in clinical and research settings. This is of particular importance as many of the existing large population cohort studies, which involve patients with normal knees and those with a background of OA, have examined knee OA using AP knee radiographs. This data would suggest that the AP technique used would be useful for assessing malalignment in these cohorts.

**Mohanty et al**[3] studied the Metaphyseo Diaphyseal Angle(MDA) and Posterior Tibial Slope(PTS) and formulated methods to find them using Xrays.The patients require an average of 67° of flexion for swing phase of gait, 83° for climbing stairs, 90° for descending stairs, and 93° to rise from a seated position. In the eastern hemisphere and in the Indian subcontinent, flexion greater than 105° is required for kneeling and squatting during activities of daily living and religious activities. Among the numerous factors affecting the postoperative flexion in a total knee replacement PTS is important, which decides about the sagital alignment of tibia. A retrospective analysis of prospectively collected data was done for 100 patients who underwent TKA. It was postulated in this study that the MDA might affect the PTS and hence affect the overall sagital alignment of the proximal tibia. The study highlights the ethnic differences in the PTS. Whereas the normal PTS has been quoted as 5-10°; racial differences in the PTS have been found. Asian population has been found to have an increased PTS as compared with Caucasian population. Moreover, it has been found that the PTS increases with the onset of osteoarthritis.

**T. Viel et al**[4] studied the Distal Femoral Torsion(DFT) using plain xrays. DFT is a crucial parameter for knee replacement surgery as it governs knee kinematics,most notably patellar tracking, as well as ligament bal-ance in flexion.Therefore, rotational malposition of the femoral component might result in failure of TKA.DFT was first evaluated in the 1990s, using computed tomography (CT).Although CT is now the reference standard for DFT ,routine CT may not be feasible given radiation exposure considerations, the limited availability of CT machines, and difficulties with bony landmark identification in some patients.These limitations have prompted studies of radiographic methods for DFT measurement.Radiographic DFT measurement is feasible in all patients who can flex their knee to 90◦.Reliability is good for anatomic Posterior Condylar Angle (aPCA) but not for surgical Posterior Condylar Angle (sPCA).

**Chiba et al**[5] studied whether skeletal parameters predict hamstring graft size during Anterior Cruciate Ligament Reconstruction (ACLR). The current data show that radiographic parameters are able to predict Semi Tendinosus(ST) graft length and 2-stranded graft diameter(GD). It is noteworthy that radiographic parameters predicted GD more accurately than anthropometric parameters. Thus, radiographic parameters should be included for predicting ST graft size.

According to **Felsony et al**[6] In summary, while anatomic alignment measured using a knee X-ray has only modest agreement with mechanical alignment assessed using a full limb film, both measures of alignment have strong and comparable predictive validity.

According to **Rana et al**[7] Several alternative methods for evaluating frontal plane knee alignment in OA have been identified, including the use of an extended anteroposterior knee radiograph (which allows visualization of the lower limb 10 cm above and below the knee), an inclinometer, or callipers.

According to **Issa et al**[8] in people with knee OA, the femur-tibia angle from a knee radiograph and the hip-knee-ankle angle from a full-limb radiograph were highly correlated.

# Total Knee Arthroplasty

## Historical background

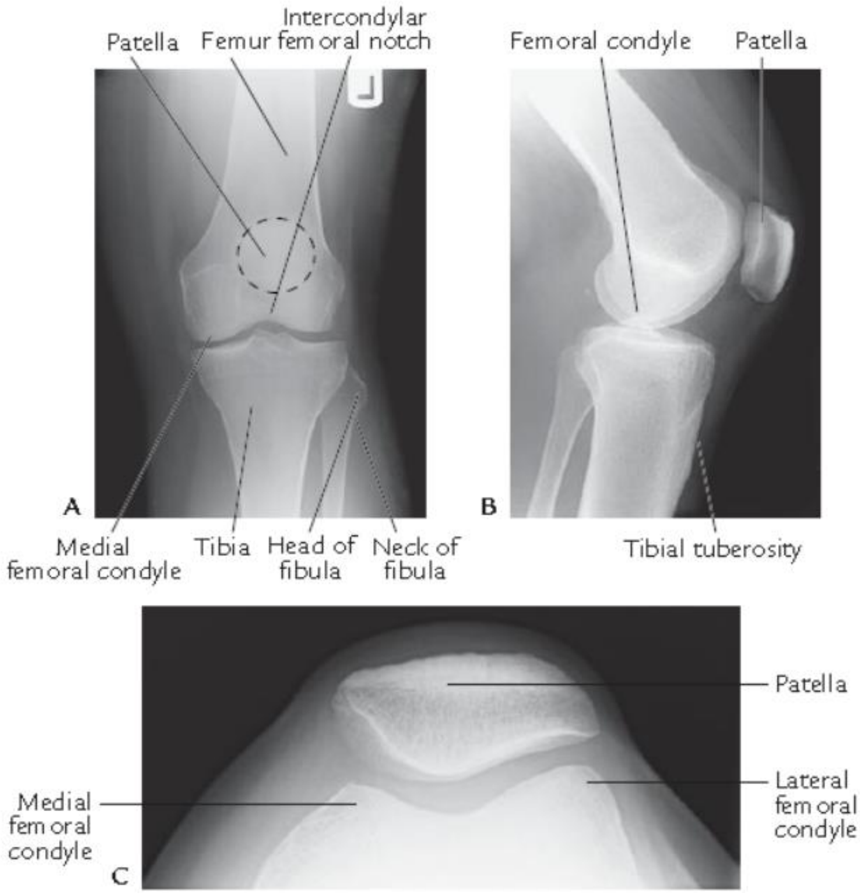
Musculoskeletal deformities are as old as mankind. The bones of ancient men provide a rich variety of these disorders that we now recognize as either congenital or acquired. The ancient Egyptians pictured their evil God Bes as a stunted midget with short legs and genu vara.

In 1741, Nicholas andry, the father of modern Orthopaedics, included the term ‘Orthopaedia” derived from Greekto suggest a straight or undeformed child. The art of preventing and correcting deformities have since adopted the picture of a “strapped crooked tree” to symbolize Orthopaedics. The introduction of diagnostic X-rays by Roentgen in 1895 and of general anaesthesia by Long in 1842,marked the end of the “Strap & Buckle” period and the beginning of “Orthopaedic operations”. Orthopaedic surgeons now correct joint deformities and replace diseases joints.

## Anatomy:

Tibiofemoral joint

The tibiofemoral joint is a complex synovial joint. The proximal tibial surface slopes posteriorly and downwards relative to the long axis of the shaft. The tilt, which is maximal at birth, decreases with age, and is more marked in habitual squatters.



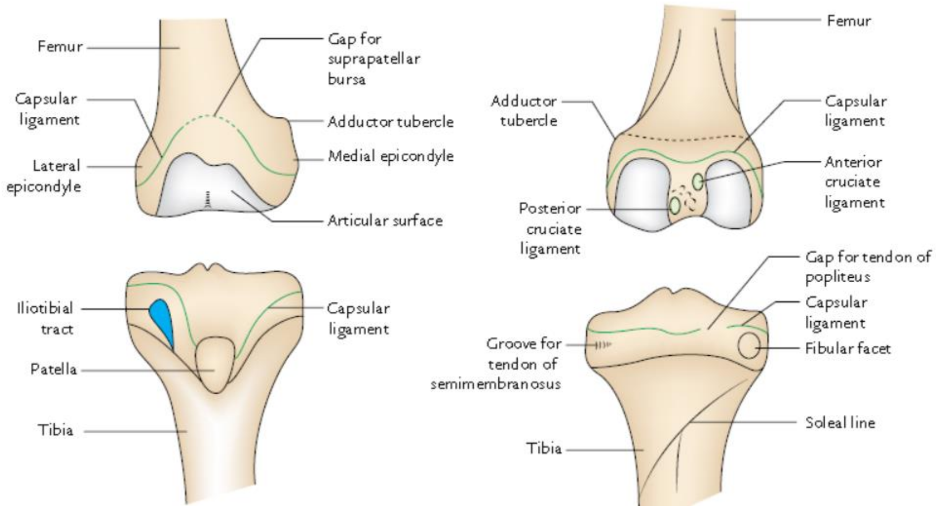

**Femoral surface**

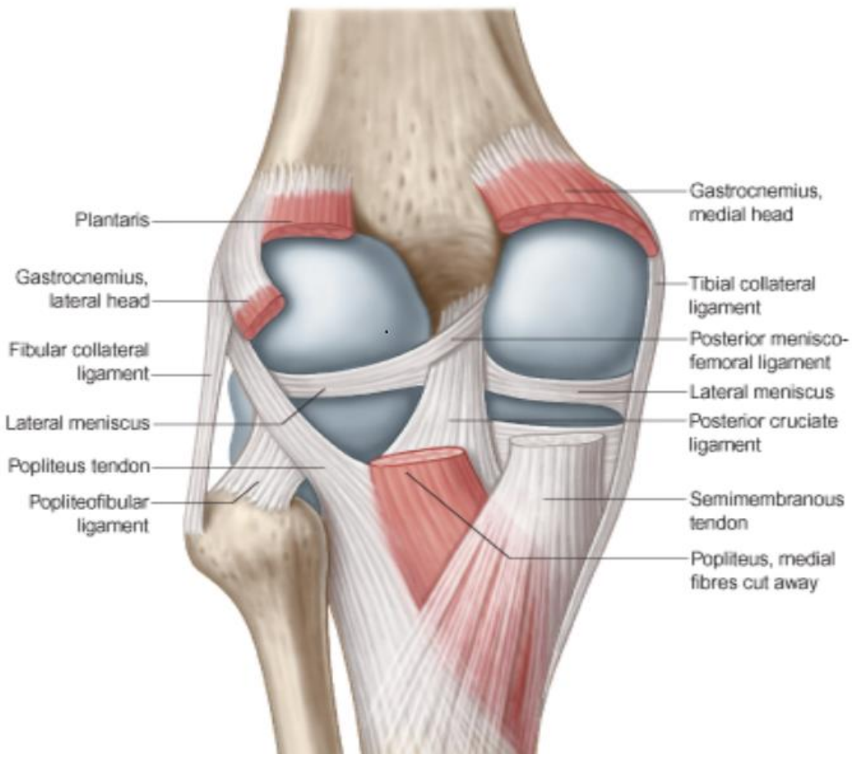
The femoral condyles, bearing articular cartilage, are almost wholly convex. The shapes of their sagittal profiles are somewhat controversial. One view is that they are spiral with a curvature increasing posteriorly ('a closing helix'), that of the lateral condyle more rapidly. An alternative view is that the articular surface for contact with the tibia on the medial femoral condyle describes the arcs of two circles. According to this view, the anterior arc makes contact with the tibia near extension and is part of a virtual circle of larger radius than the more posterior arc, which makes contact during flexion. Laterally there may only be a single radius of curvature of a single arc.

**Capsule:**

The capsule is a fibrous membrane of variable thickness. The individual thickenings are referred to as discrete ligaments. Anteriorly it is replaced by the patellar tendon and does not pass proximal to the patella or over the patellar area. Elsewhere it lies deep to expansions from vasti medialis and lateralis, separated from them by a plane of loose connective tissue containing blood vessels. The expansions are attached to the patellar margins and patellar tendon, extending back to the corresponding collateral ligaments and distally to the tibial condyles. They form medial and lateral patellar retinacula, the lateral being augmented by the iliotibial tract.

Posteriorly the capsule contains vertical fibres that arise from the articular margins of the femoral condyles and intercondylar notch and from the proximal tibia. The fibres mainly pass down and medially. The oblique popliteal ligament is a well-defined thickening across the posteromedial capsule, and includes a contribution from the extensive insertion of semimembranosus.




# LIGAMENTS

## Cruciate ligaments

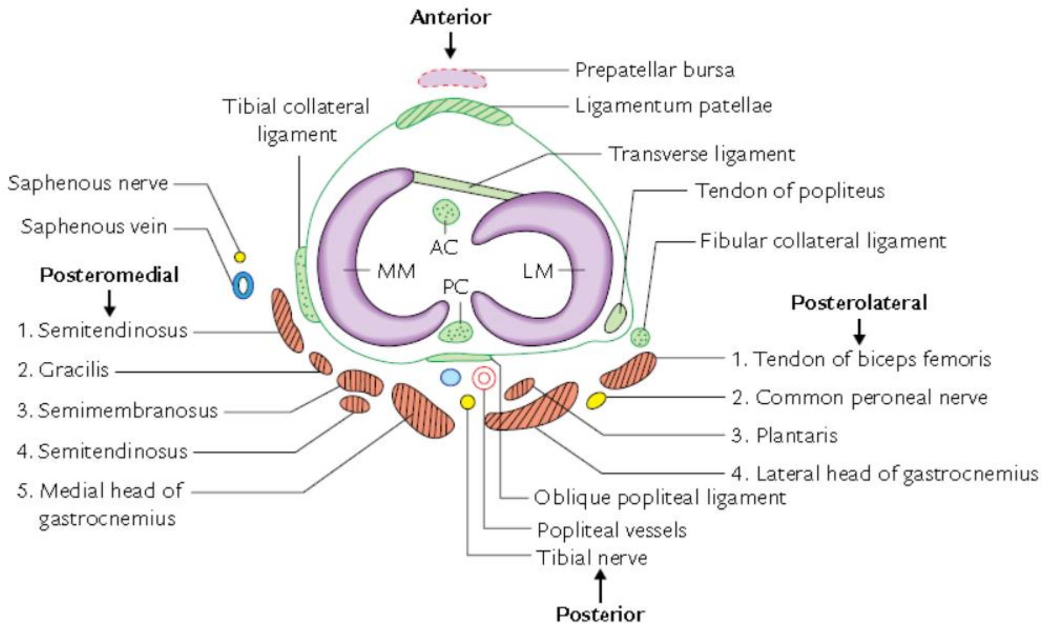
The cruciate ligaments are very strong and are located a little posterior to the articular centre. They are termed cruciate because they cross: anterior and posterior refer to their tibial attachments. Synovial membrane almost surrounds the ligaments but is reflected posteriorly from the posterior cruciate to adjoining parts of the capsule. The intercondylar part of the posterior region of the fibrous capsule therefore has no synovial covering.

The anterior cruciate ligament is attached to the anterior intercondylar area of the tibia, just anterior and slightly lateral to the medial tibial eminence, partly blending with the anterior horn of the lateral meniscus. It ascends posterolaterally, twisting on itself and fanning out to attach high on the posteromedial aspect of the lateral femoral condyle. Its average length is 38 mm, and average width is 11 mm. It is formed of two, or possibly three, functional bundles. These are not distinct visually but can be identified by dissection. They are named anteromedial, intermediate, and posterolateral, according to their tibial attachments.

The posterior cruciate ligament is thicker and stronger than the anterior cruciate ligament. This is perhaps surprising because its rupture is usually better tolerated than that of the anterior cruciate. Its average length is 38 mm and average width is 13 mm.

The posterior cruciate ligament is attached to the lateral surface of the medial femoral condyle and extends up onto the anterior part of the roof of the intercondylar notch, where its attachment is extensive in the anteroposterior direction. Its fibres are adjacent to the articular surface. They pass distally and posteriorly to a fairly compact attachment posteriorly in the intercondylar region and in a depression on the adjacent posterior tibia. This gives a fan-like structure in which fibre orientation is variable. Anterolateral and posteromedial bundles have been defined: they are named (against convention) according to their femoral attachments. The anterolateral bundle tightens in flexion whilst the posteromedial is tight in extension of the knee. Each bundle slackens as the other tightens. Unlike the anterior cruciate ligament, it is not isometric during knee motion, i.e. the distance between attachments varies with knee position.

**Relationship of knee joint to the surrounding structures:**




## MOVEMENTS AND MUSCLES

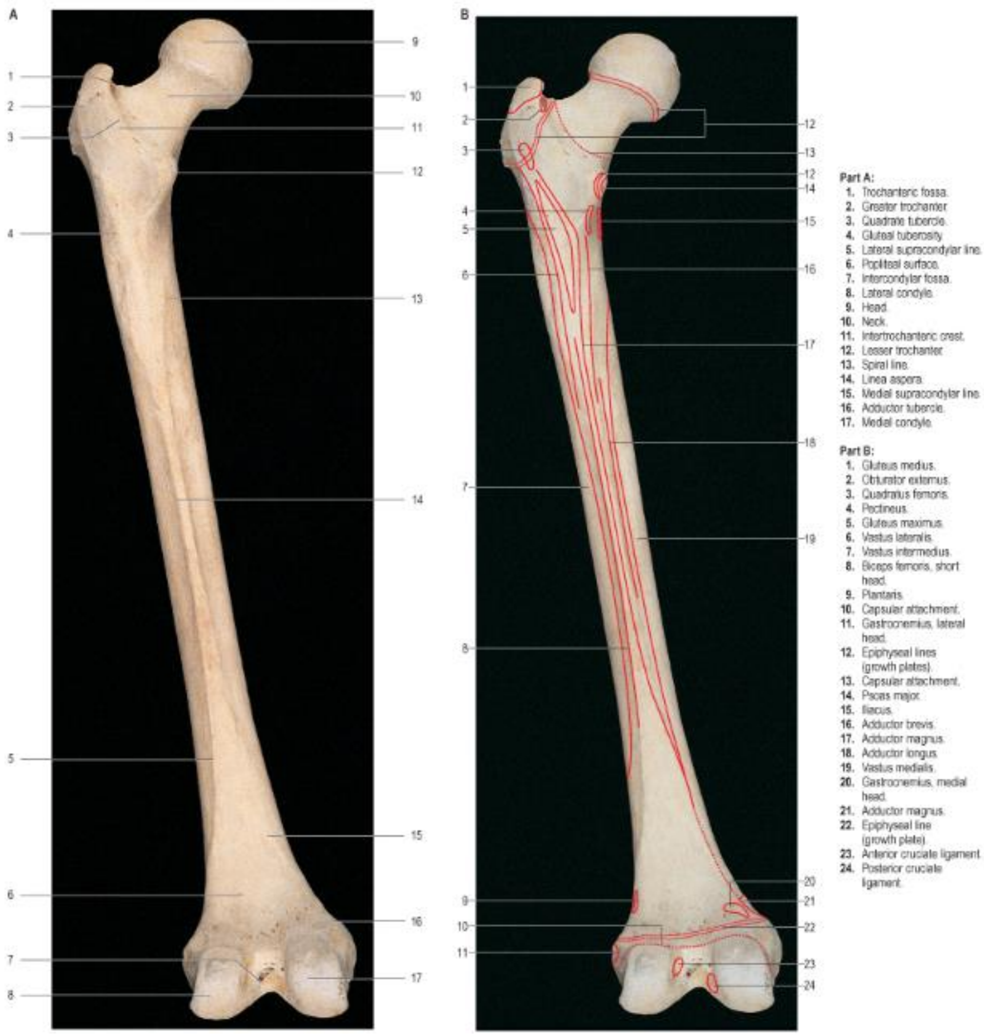
### Movements

Movements at the knee are customarily described as flexion, extension, internal (medial) and external (lateral) rotation. Flexion and extension differ from true hingeing in that (a) the articular surface profiles of the femoral and tibial articular surfaces produce a variably placed axis of rotation during the flexion arc, and (b) when the foot is fixed, flexion entails corresponding conjunct (coupled) external (lateral) rotation. These conjunct rotations are a product of the geometry of the articular surfaces and, to an extent, the disposition of the associated ligaments. There is differential motion in the medial and lateral tibiofemoral compartments. Laterally there is considerable displacement of the femur on the tibia, with rolling as well as sliding at the joint surface, whereas medially for most of the flexion arc there is minimal relative motion of the femur and tibia, with the motion being almost exclusively one joint surface sliding on the other. In full flexion the lateral femoral condyle is close to subluxation off the posterior lateral tibia. Medially there is only significant posterior femoral displacement beyond 120° by passive means. The menisci move with the femoral condyles, the anterior horns more than the posterior, and the lateral far more than the medial.

The axial rotations have a smaller range than the arc of flexion and extension. These rotations are conjunct, and integral with flexion and extension, i.e. They are obligatory. They can also be adjunct and independent, i.e. Voluntary, and are best demonstrated with the knee semi-flexed. Therefore the degree of axial rotation varies with flexion and extension.

**FEMUR**

The femur is the longest and strongest bone in the human body. Its length is associated with a striding gait, its strength with weight and muscular forces. Its shaft, almost cylindrical in most of its length and bowed forward, has a proximal round, articular head projecting mainly medially on its short neck, which is a medial curvature of the proximal shaft. The distal extremity is more massive and is a double 'knuckle' (condyle) that articulates with the tibia. In standing, the femoral shafts are oblique and their heads are separated by the pelvic width. The shafts converge downwards and medially to the knees and almost touch: they lie below the hip joints. Since the tibia and fibula descend vertically from the knees, the ankles are also in the line of body weight in standing or walking. Femoral obliquity varies but is greater in women, reflecting the relatively greater pelvic breadth and shorter femora. Proximally the femur consists of a head, neck, and greater and lesser trochanters.




**Shaft**

The shaft is surrounded by muscles and is impalpable. The distal anterior surface, for 5-6 cm above the patellar articular surface, is covered by a suprapatellar bursa, between bone and muscle. The distal lateral surface is covered by vastus intermedius. The medial surface, devoid of attachments, is covered by vastus medialis.

The shaft is narrowest centrally, expanding a little proximally, particularly towards its distal end. Its long axis makes an angle of c.10° with the vertical, and diverges c.5-7° from the long axis of the tibia. Its middle third has three surfaces and borders. The extensive anterior surface, smooth and gently convex, is between the lateral and medial borders, which are both round and indistinct. The posterolateral surface is bounded posteriorly by the broad, rough linea aspera, usually a crest with lateral and medial edges. Its subjacent compact bone is augmented to withstand compressive forces, which are concentrated here by the anterior curvature of the shaft. The linea aspera receives adductor longus, intermuscular septa and the short head of biceps femoris, inseparably blended at their attachment. Perforating arteries cross the linea laterally under tendinous arches in adductor magnus and biceps. Nutrient foramina, directed proximally, appear in the linea aspera, varying in number and site, one usually near its proximal end, a second usually near its distal end. The medial surface is posteromedial, smooth like the others, bounded in front by the indistinct medial border and behind by the linea aspera. In its proximal third the shaft has a fourth, posterior surface, bounded medially by a narrow, rough spiral line that is continuous proximally with the intertrochanteric line and distally with the medial edge of linea aspera. Laterally this surface is limited by the broad, rough, gluteal tuberosity, ascending a little laterally to the greater trochanter and descending to the lateral edge of the linea aspera. In its distal third the shaft also has a fourth, posterior surface, between the medial and lateral supracondylar lines, which is continuous above with the corresponding edges of the linea aspera. The lateral line is most distinct in its proximal two-thirds, where the short head of biceps femoris and lateral intermuscular septum are attached. Its distal third has a small rough area for the attachment of plantaris, often encroaching on the popliteal surface. The medial line is indistinct in its proximal two-thirds, where vastus medialis is attached. Proximally, the shaft is crossed by femoral vessels entering the popliteal fossa from the adductor canal. It is often sharp for 3 or 4 cm proximal to the adductor tubercle.

The popliteal surface is also triangular. In its distal medial part it is rough and slightly elevated. Forming the proximal floor of the popliteal fossa, it is covered by variable amounts of fat that separate the popliteal artery from bone. The superior medial genicular artery, a branch of the popliteal artery, arches medially above the medial condyle. It is separated from bone by the medial head of gastrocnemius. The latter is attached a little above the condyle; further distally there may be a smooth facet underlying a bursa for the medial head of gastrocnemius. More medially, there is often an imprint proximal to the articular surface: in flexion this is close to a rough tubercle on the medial tibial condyle for the attachment of semimembranosus. The superior lateral genicular artery arches up laterally proximal to the lateral condyle but is separated from bone by the attachment of plantaris to the distal part of the lateral supracondylar line.


Part A:
1. Head.
2. Neck.
3. Intertrochanteric line.
4. Lesser trochanter.
5. Adductor tubercle.
6. Medial epicondyle.
7. Medial condyle.
8. Greater trochanter.
9. Shaft.
10. Lateral condyle.
11. Lateral epicondyle.
12. Patellar surface.

Part B:
1. Epiphyseal lines (growth plates).
2. Psoas major.
3. Vastus medialis.
4. Capsular attachment.
5. Piriformis.
6. Gluteus minimus.
7. Vastus lateralis.
8. Capsular attachment.
9. Vastus intermedius.
10. Articularis genu.
11. Epiphyseal line (growth plate).

**Distal end**

The distal end of the femur is widely expanded as a bearing surface for transmission of weight to the tibia. It has two massive condyles, which are partly articular. Anteriorly the condyles unite and continue into the shaft; posteriorly they are separated by a deep intercondylar fossa and project beyond the plane of the popliteal surface. The articular surface is a broad area, like an inverted U, for the patella and the tibia. The patellar surface extends anteriorly on both condyles, especially the lateral. It is transversely concave, vertically convex and grooved for the posterior patellar surface. The tibial surface is divided by the intercondylar fossa but is anteriorly continuous with the patellar surface. Its medial part is a broad strip on the convex inferoposterior surface of the medial condyle, and is gently curved with a medial convexity. Its lateral part covers similar aspects of the lateral condyle but is broader and passes straight back. The tibial surfaces are transversely convex in all directions. The anteroposterior curvature of both surfaces is not uniform. The exact pattern is controversial. One view is that in both tibial portions of the femoral condyles the sagittal radius of curvature is ever decreasing (a 'closing helix'). More recently it has been suggested that the medial articular surface describes arcs of two circles. The more posterior has a smaller radius. Laterally there may only be one arc of fixed curvature with a radius similar to that of the posterior arc of the medial femoral articular surface. These differences are important determinants of knee joint motion.


**1.** Medial oblique groove. **2.** Semilunar area. **3.** Medial condyle. **4.** Patellar surface. **5.** Lateral oblique groove. **6.** Intercondylar notch. **7.** Lateral epicondyle. **8.** Lateral condyle.

**Intercondylar fossa**

The intercondylar fossa separates the two condyles distally and behind. In front it is limited by the distal border of the patellar surface, and behind by an intercondylar line, separating it from the popliteal surface. It is intracapsular but largely extrasynovial. Its lateral wall, the medial surface of the lateral condyle, bears a flat posterosuperior impression which spreads to the floor of the fossa near the intercondylar line for the proximal attachment of the anterior cruciate ligament. The medial wall of the fossa, i.e. The lateral surface of the medial condyle, bears a similar larger area, but far more anteriorly, for the proximal attachment of the posterior cruciate ligament. Both impressions are smooth and largely devoid of vascular foramina, whereas the rest of the fossa is rough and pitted by vascular foramina. A bursal recess between the ligaments may ascend to the fossa. The capsular ligament and, laterally, the oblique popliteal ligament, are attached to the intercondylar line. The ligamentum mucosum (infrapatellar synovial fold or plica) is attached to the anterior border of the fossa.

**Lateral condyle**

The lateral condyle is larger anteroposteriorly than the medial. Its most prominent point is the lateral epicondyle to which the lateral collateral ligament is attached. A short groove, deeper in front, separates the lateral epicondyle inferiorly from the articular margin. This groove allows the tendon of popliteus to run deep to the lateral collateral ligament and insert inferior and anterior to the ligament insertion. Adjoining the joint margin is a strip of condyle, 1 cm broad. It is intracapsular and covered by synovial membrane except for the attachment of popliteus.

The medial surface is the lateral wall of the intercondylar fossa. Its lateral surface projects beyond the shaft. Part of the lateral head of gastrocnemius is attached to an impression posterosuperior to the lateral epicondyle.

**Medial condyle**

The medial condyle has a bulging convex medial aspect, which is easily palpable. Proximally its adductor tubercle, which may only be a facet rather than a projection, receives the tendon of adductor magnus. The medial prominence of the condyle, the medial epicondyle, is anteroinferior to the tubercle. The lateral surface of the condyle is the medial wall of the intercondylar fossa. The condyle projects distally so that, despite the obliquity of the shaft, the profile of the distal end is almost horizontal. A curved strip, c.1 cm wide, adjoining the medial articular margin, is covered by synovial membrane and is inside the joint capsule. Proximal to this, the medial epicondyle receives the medial collateral ligament.

**Structure**

The femoral shaft is a cylinder of compact bone with a large medullary cavity. The wall is thick in its middle third, where the femur is narrowest and the medullary cavity most capacious. Proximally and distally the compact wall becomes progressively thinner, and the cavity gradually fills with trabecular bone. The extremities, especially where articular, consist of trabecular bone within a thin shell of compact bone, their trabeculae being disposed along lines of greatest stress. At the proximal end the main trabeculae form a series of plates orthogonal to the articular surface, converging to a central dense wedge, which is supported by strong trabeculae passing to the sides of the neck, especially along its upper and lower profiles. Force applied to the femoral head is therefore transmitted to the wedge and thence to the junction of the neck and shaft. This junction is strengthened by dense trabeculae extending laterally from the lesser trochanter to the end of the superior aspect of the neck, thus resisting tensile or shearing forces applied to the neck through the head. Tensile and compressive tests indicate that axial trabeculae of the femoral head withstand much greater stresses than peripheral trabeculae. A smaller bar across the junction of the greater trochanter with the neck and shaft resists shearing produced by muscles attached to it. These two bars are proximal layers of arches between the sides of the shaft and transmit to it forces applied to the proximal end. A thin vertical plate, the calcar femorale, ascends from the compact wall near the linea aspera into the trabeculae of the neck. Medially it joins the posterior wall of the neck; laterally it continues into the greater trochanter, where it disperses into general trabecular bone. It is thus in a plane anterior to the trochanteric crest and base of the lesser trochanter. At the distal end of the femur, trabeculae spring from the entire internal surface of compact bone, descending perpendicular to the articular surface. Proximal to the condyles these are strongest and most accurately perpendicular. Horizontal planes of trabecular bone, arranged like crossed girders, form a series of cubical compartments.

**Modern prosthesis evaluation and design:**

Although many total knee designs predate the total condylar prosthesis designed by Insall and others, its introduction in 1973 marked the beginning of the total knee arthroplasty (TKA) era . This prosthesis design allowed mechanical considerations to outweigh the desire to reproduce anatomically the kinematics of normal knee motion. Influenced largely by the previous Imperial College/London Hospital design, both cruciate ligaments were sacrificed, with sagittal plane stability maintained by the articular surface geometry. The original cemented total condylar prosthesis set the standard for survivorship of total knee arthroplasty. New designs have now evolved to the point where several have reported long-term survivorships of over 80% at 15- to 20-year follow-up. Since the concept of the total condylar design was introduced, TKR design has yet to see another major leap in advancement. The original design had symmetric femoral condyles with a decreasing sagittal radius of curvature posteriorly. The symmetric condyles were individually convex in the coronal plane. The double-dished articular surface of the tibial polyethylene component was perfectly congruent with the femoral component in extension and congruent in the coronal plane in flexion. Translation and dislocation of the components were resisted by the anterior and posterior lips of the tibial component and the median eminence. The tibial component has a metaphyseal stem to resist tilting of the prosthesis during asymmetric loading. The tibial component originally was all-polyethylene, but metal backing was added later to allow more uniform stress transfer to the underlying cancellous metaphyseal bone and to prevent polyethylene deformation. The patella was resurfaced with a dome-shaped, all-polyethylene patellar component with a central fixation lug. Many of these design characteristics are retained in modern designs. Concurrent with the development of the cruciatesacrificing total condylar prosthesis, the duopatellar prosthesis was developed with the sagittal plane contour of thefemoral component being anatomically shaped. This prosthesis included retention of the posterior cruciate ligament (PCL). Originally, the medial and lateral tibial plateau components were separate, but this was soon revised to a onepiece tibial component with a cutout for retention of the PCL. The patellar component of the duopatellar prosthesis was an all-polyethylene dome similar to that used in the total condylar knee. The duopatellar prosthesis evolved into the kinematic prosthesis, which was widely used in the 1980s. Two early criticisms of the total condylar prosthesis were its tendency to subluxate posteriorly in flexion if the flexion gap was larger than the extension gap and its lack of femoral rollback and smaller range of flexion if the PCL was not functioning. By not "rolling back," the posterior femoral metaphysis in a total condylar knee impinged against the tibial articular surface at approximately 95 degrees of flexion. The early clinical reviews of the total condylar prosthesis documented average flexion of only 90 to 100 degrees. To correct these problems, the Insall-Burstein posterior cruciate-substituting or posterior-stabilized (PS) design was developed in 1978 by adding a central cam mechanism to the articular surface geometry of the total condylar prosthesis . The cam on the femoral component engaged a central post on the tibial articular surface at approximately 70 degrees of flexion and caused the contact point of the femoral-tibial articulation to be posteriorly displaced, effecting femoral rollback and allowing further flexion. Most current total knee designs are derivatives of the Insall-Burstein and kinematic designs. During the late 1980s and 1990s, patellofemoral complications became one of the primary causes for reoperation in TKA. Consequently, improved reconstruction of the patellofemoral joint has received attention in more recent designs. Newer designs incorporate greater areas of patellofemoral contact through a larger range of motion and asymmetric anterior flanges designed to resist patellar subluxation and soft-tissue reaction from articulating on a short trochlear groove. Some total knee systems have incorporated a deep-dish design as one of their available modular tibial polyethyleneoptions. This design is similar to the original total condylar design that uses sagittal plane concavity or dishing alone to control anterior and posterior translational stability. A comparison of deep-dish components withposterior-stabilized devices using the same femoral components found no difference at follow-up in range of motion, ability to climb or descend stairs, or pain scores. This deepdish design incorporated many of the previously mentioned advantages of cruciate sacrifice without the obligatory bone sacrifice in the intercondylar region of the femur, which may predispose to fracture. With proper flexion-extension gap balancing, posterior impingement in flexion was reported to be avoided, yielding flexion similar to the posterior-stabilized design. Posterior cruciate–retaining (CR) total knee designs often incorporate a deep-dish or ultra-congruent option for a tibial polyethylene insert to enhance roll back and higher flexion. Many designs, however, have still shown a tendency for the femoral articulation to roll forward with increasing flexion. Range of motion after posterior cruciate– retaining TKA has been reported to be improved when the posterior condylar offset is re-established. If the posterior condyles are over resected, the posterior aspect of the tibia may butt up against the posterior aspect of the femur and result in suboptimal flexion. Later reports have shown that measuring this variable radiographically is difficult and that a combination of variables including implant design and tibial slope also play a role in the amount of flexion obtained. Some newer PS total knee designs have incorporated more complex post-cam interactions and even a dual-cam mechanism in which the anterior aspect of the post drives a screw-home mechanism as the knee is moved into full extension. The transverse plane rotation pattern in this type of design has been shown to be closer to normal knee kinematics than with older posterior-stabilized designs. Manymanufacturers now change the positioning of the post and the cam, as well as their geometry, to guide a more normal tibiofemoral articulation pattern throughout the range of motion.

**Mobile bearing prosthesis:**

Mobile-bearing knee designs have seen an increase in popularity, and efforts have been made to the United States Food and Drug Association (FDA) to down-classify these devices for clearance purposes. The meniscal-bearing version of the low contact stress (LCS) prosthesis developed by Buechel and others incorporated many of the features of the earlier Oxford knee. Individual polyethylene menisci articulate with the femoral component above and with a polished tibial baseplate below. The LCS design has additional dovetailed arcuate grooves on the tibial baseplate that control the anteroposterior course of the menisci. The femoral component has a decreasing radius of curvature posteriorly. This modification of the Oxford design decreases the posterior excursion of the menisci in flexion, helping to decrease the incidence of posterior extrusion of the menisci. The LCS total knee system also includes a rotating platform design with congruent tibiofemoral geometry in extension similar to other current deep-dish designs; however, the tibial polyethylene is additionally free to rotate within the stem of the tibial baseplate. This design has had rare rotational dislocations of the tibial inserts because of inadequate flexion-extension gap balancing, but it has exhibited excellent longevity. Callaghan et al. reported a 100% prosthesis survival rate in 82 patients at a minimum of 9-year follow-up of the cemented rotating platform LCS design. In a later follow-up study, Callaghan et al. reported the status of 53 knees in 37 of these patients who were still living at a minimum follow-up of 15 years. None of the knees had required revision because of loosening, osteolysis, or wear; three knees had required reoperation (two for periprosthetic fractures and one for infection), but none of the components was revised as part of the reoperations. Buechel, one of the developers of the LCS design, reported a 98% 20-year survivorship with this design and a similar survivorship at 18 years with the cementless rotating platform design. A recent meta-analysis comparing outcomes with fixed-bearing and mobile-bearing TKA found no clinically significant differences in patient-specific or clinical outcome parameters. One reason these implant designs are not offered by many manufacturers is their designation as a class III device by the FDA. In vivo fluorokinematic studies have shown that the bearing rotation in the transverse plane may be nonphysiologic in some patients. A recent meta-analysis found that there was moderate to low quality evidence that cruciate-retaining mobile-bearing TKA was as good as fixed-bearing TKA. Potential advantages of mobile-bearing knees include lower contact stresses at the articulating surfaces, rotational motion of the tibial polyethylene during gait, and selfalignment of the tibial polyethylene compensating for small rotational malalignment of the tibial baseplate during implantation. Recent studies have found a higher revision rate in both the short-term and mid-term follow-up period with a mobile-bearing insert compared with fixed-bearing TKA. Whether mobile-bearing designs will outperform fixedbearing designs is yet to be determined and may be specific to individual manufacturer's design.

**Prosthesis system**

Different types of prostheses are necessary for varying amounts of arthritic involvement, deformity, laxity, and bone loss. Prostheses used range from unicompartmental designs for single-compartment disease with minimal deformity to hinged prostheses for severe deformity and or ligamentous deficiencies and for salvage procedures. Many surgeons advocate the use of PCL-retaining prostheses for mild deformity and PCL-substituting designs for more severe deformity while for many surgeons the choice is based on training and experience. Knee prosthesis manufacturers have developed prostheses that offer either PCL retention or PCL substitution through modular tibial polyethylene inserts and PCLsubstituting and PCL-retaining femoral components that require similar bone cuts. These prostheses typically use shared operative instrumentation and allow an intraoperative change from PCL retention to PCL substitution or even a constrained condylar design. If balancing of the PCL is difficult, the arthroplasty can be converted to a PCL-substituting design with relative ease in most cases. Many prosthesis designs also include a tibial polyethylene component with significant dishing (or increased AP congruency or constraint) in the sagittal plane for optional use instead of the posterior-stabilized design when the PCL is incompetent. Modular stems and metal augments and constrained condylar components are typically available in most systems. Many other factors are important in prosthesis design and selection, including prosthesis fixation, the handling of the patellofemoral articulation, modularity, and polyethylene issues. These are discussed in subsequent sections of this chapter. It is the surgeon's responsibility to understand the indications, contraindications, expected functional outcome, and longevity for each prosthesis type and for specific prostheses. Every surgeon should be familiar with the options and instrumentation of his or her choice to ensure that all basesare covered in the operating room. Long-term followup studies will continue to improve our understanding of appropriate indications for the variety of available knee prostheses.

**Alignment of normal knee and its relationship to Total Knee Arthroplasty**

There is an interplay between the anatomy of the articular surfaces, their relationship to the axes of rotation of the normal knee, and the four principle ligaments that stabilize the knee that gives the knee its complex and spectacularly successful kinematics.These kinematics are complex, but now are well understood owing to clinical and biomechanical research.With resurfacing total knee replacement comes the possibility of altering this complex interplay to the detriment of both function and survival of the prosthetic reconstruction.It is imperative that the surgeon understand this interplay and seek to reproduce it through the replacement surgery.Moreover, it is also important to understand the specific consequences of the common malalignments so they can be detected and corrected prior to finishing the arthroplasty.

The alignment parameters of the normal knee have been understood for a long time and are not really a source of controversy. Moreover, their relationship to the kinematic function of the normal knee has also been well documented. Although the kinematic function of the knee is quite complex, the relationship of ligament structure to the normal anatomy of the knee has been understood since the early studies of Brantigan and Voshell. Within the parameters of the normal knee, it is the ligament function which has received the greatest attention in terms of the overall knee function. The reason for this is that the ligaments are much more vulnerable to injury than are the normal aspects of alignment.However,in the case of total knee replacement (TKR) with resection of the articular portions of the joint and their replacement by artificial parts,the reconstitution of normal alignment is not guaranteed. The authors believe that the relationship between the alignment of the component parts and subsequent function has been oversimplified. It is the purpose of this chapter first to define the normal alignment of the knee, second to define the relationship between alignment and ligament balance in TKR, and finally to outline the consequences of malalignment in relationship to failure of TKR.

The ultimate goal of all TKRs is to produce a well aligned prosthesis with good ligament balance.One without the other is unacceptable. Although it is possible to achieve excellent overall alignment and still fail to achieve ligament balance,if the ligament imbalance has been created by malalignment,balance can seldom be achieved by the common techniques of ligament loosening or tightening. In addition, the arthritic process, and its attendant deformity can result in significant loosening or stretching of ligaments. It is also unacceptable for the surgeon to balance that instability by producing malalignment. By understanding the normal alignment of the human knee, its relationship to normal ligament function and kinematics, and the consequences of malalignment, the surgeon will be well positioned to achieve a high degree of accuracy in both alignment and balance.

**Normal Alignment**

Although the relationship of the joint line to the common reference axes varies slightly with the length of the femur and the breadth of the pelvis, for most individuals the joint line is horizontal when the leg is positioned for single- leg stance.In single-leg stance the ankle must be brought directly under the center of gravity.This means that the lower leg and the mechanical axis are inclined toward the midline by 3°. This can vary by as much as ±1.5° depending on the breadth of the pelvis and the length of the femur.The relationship of the distal femoral joint line to the femoral shaft averages 9° and varies from 7° to 11°. In our experience of measuring this relationship in thousands of patients we have seen only one patient in whom the joint line was actually perpendicular to the mechanical axis. The tibial shaft is normally parallel to the mechanical axis and is therefore 87° to the joint line and not perpendicular to the joint line.This relationship of the joint line to the mechanical and anatomical axes leads to several difficulties in describing deviations from the normal. For example, it is common to describe the 87° angle between the joint line and the tibial shaft as being in 3° ofvarus, indicating that the 87° is on the medial side and 3° from perpendicular. If that relationship were 85°, then it would be logical to describe this as 5° of varus but it would be only 2° of varus deformity. This becomes even more confusing because the vast majority of TKRs today are implanted with a tibial cut that is perpendicular to the mechanical axis and therefore is actually implanted with 3° of valgus malalignment.We will come back to this point in discussing alignment in regards to TKR. Much of the focus in the literature concerning alignment in both the normal and the replaced knee is placed only on alignment in the coronal plane.However, in both instances, alignment in all three planes needs to be addressed.


Long standing X-ray with normal alignment. With the ankles together, single-leg stance is simulated. The mechanical axis is 87° to the joint line, which is horizontal in the stance position.

**Femoral Rotational Alignment**

The distal femur has a characteristic relationship to the coronal plane. With the posterior aspect of the medial and lateral femoral condyles defining the coronal plane,the femoral shaft is in neutral rotation vis-a-vis the hip and the knee. In this position, the lateral epicondyles can be seen to be more posterior than the medial epicondyle. The angle between a line connecting the epicondyles and a line defining the posterior plane of the condyles is about 3°. Some authors have used the epicondylar axis as the rotational reference of choice for determining femoral rotation in TKR.The rotational reference that is used is less important at this point in the discussion than the relationship between the position of the posterior condyles in space to that rotational reference. There is no question that the posterior lateral condyle is closer to the epicondylar axis than the posterior medial condyle. Another feature of the anatomy of the distal femur is the relationship of the trochlea to the rotational axis of the femur. The lateral facet of the trochlea is projected more anterior than the medial facet. This relationship is seen on the typical patellar skyline view, and its relationship is also a good secondary check for rotational alignment of the femoral component in TKR.

**Tibial Rotational Alignment**

The rotational alignment of the tibia is best seen when the entire tibial plateau is exposed. When the entire tibial plateau can be seen, the transverse axis passes between the midpoint of the medial and lateral plateaus. The neutral rotation of the tibial plateau places the tibial tubercle just lateral to the midline of the tibia. The axis between the medial and lateral maleoli is not reliable. The tibial tubercle alone is also not a reliable rotational reference because it is a single point and it takes two points to define a plane. Finally, the posterior margins of the tibial plateau are not reliable references either,because the medial tibial plateau characteristically projects more posteriorly than the lateral tibial plateau.

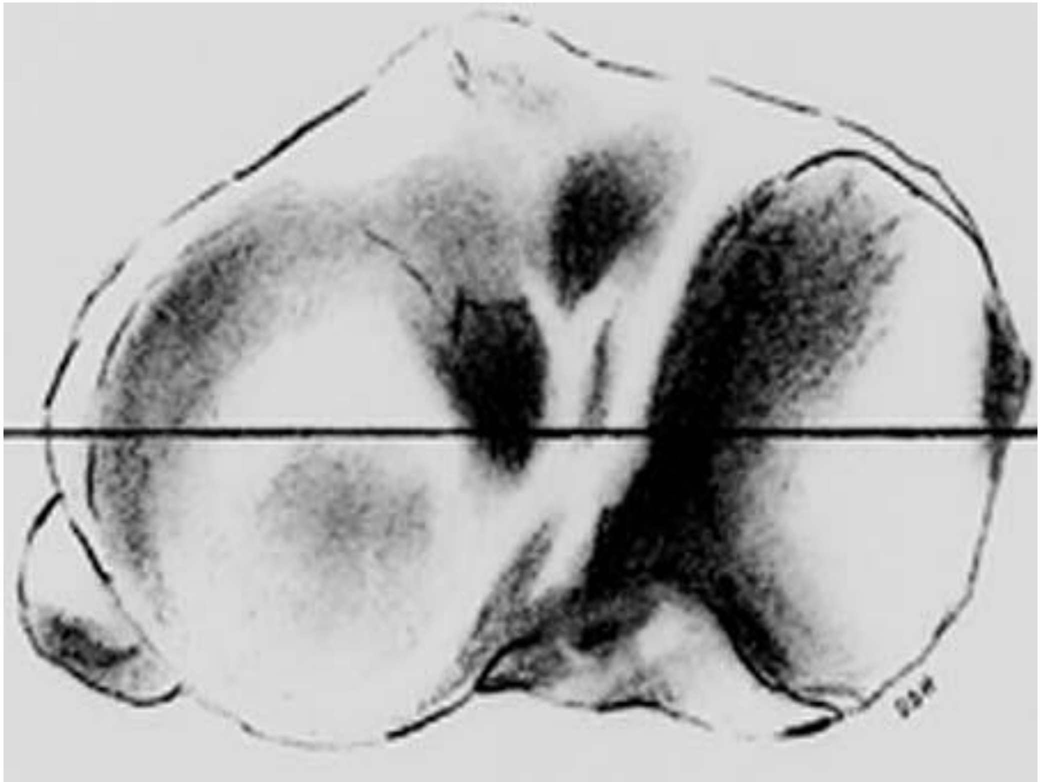
## SAGITTAL PLANE ALIGNMENT

### Femur

The distal portions of the femoral condyles are somewhat flattened, particularly on the lateral side (they have a much larger radius of curvature distally than posteriorly). That portion of the femoral condyles that makes contact with the tibial plateaus with the knee in full extension is the distal reference plane and is perpendicular to the coronal plane of the thigh. Although this is roughly the same plane as the femoral shaft, it is not exactly the same plane, because of the anterior bow of the femur. A more technically accurate reference plane would be the plane that connects the middle of the greater trochanter and the lateral epicondyle. In using an extramedullary alignment system, these are the references.Most TKR instrumentation systems in use today provide for an intramedullary rod placed in the femoral canal.Although this risks placing the femoral component in a few degrees of flexion, it is a generally reliable reference.Evolving computer navigation will likely resolve the inaccuracies of both the extra- and intramedullary reference methods for the distal femoral cut.

**Tibia**

The tibial plateaus are sloped posteriorly 7°–10°, referable to the coronal plane of the lower leg. It should be noted that the lower leg is conical from proximal to distal and the coronal plane does not parallel the anterior tibial shaft. The fibula is a more reliable coronal plane reference. TKR instrumentation systems frequently offer both intra- and extramedullary alignment references. Both can be effective for flexion/extension alignment of the tibial component.



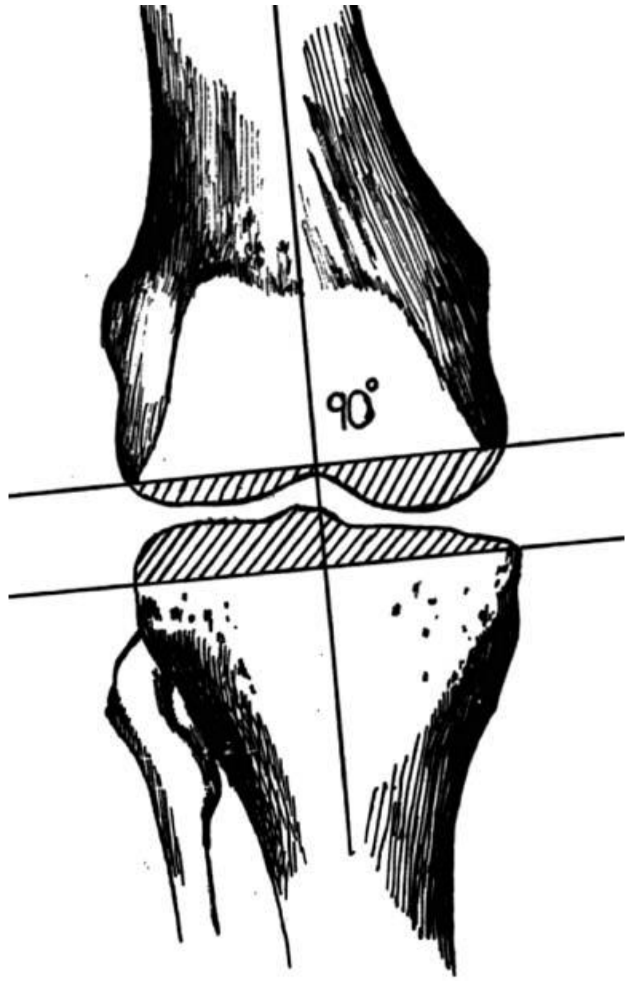
**RELATIONSHIP OF ALIGNMENT TO KINEMATIC**

**Function of the Knee**

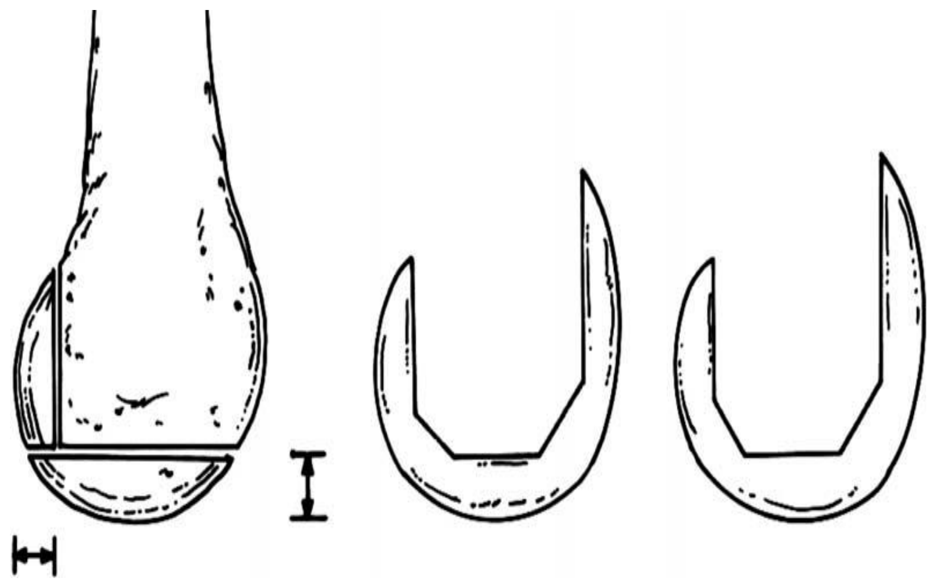
Kinematic function of both the normal and the replaced knee is the subject of other chapters, but the relationship of ligament function and component placement to alignment parameters must be understood in both the normal and the replacement scenarios. Kapandji has best illustrated these concepts. The collateral and cruciate ligaments of the knee function normally only when they bear a normal relationship to the anatomy of the normal knee. The axes around which flexion/extension occurs encompass the epicondyles, which are located within the concavity of a line connecting the instant centers of rotation of the knee. Because of this location, the collaterals are taut in extension and become relaxed as flexion proceeds. This relaxation is a function of both the position of attachment and the posterior slope of the tibial plateaus. Imagine that the attachment point of the MCL were picked up and physically moved anterior to its anatomical attachment. It can now be seen that the ligament would be tightened in flexion, a condition that would actually block flexion. In the natural knee the articular surfaces cannot practically be repositioned, but in total knee replacement it is very easy to do so. In other words, it should be possible to perfectly align the components with the alignment references that have been outlined above and thereby maintain the relationship of the ligaments to the articulating surfaces of the new construct. Alignment references for the normal knee consist of rotational alignment around the x-, y-, and z-axes.However, in TKR, alignment also includes position along the alignment axes. It is only when all of these parameters are addressed and successfully fulfilled that a total knee replacement can function in a kinematically normal way. If the surgeon is willing to use a totally constrained prosthesis, most of the alignment parameters can be ignored. Varus/valgus alignment has an obvious cosmetic component and would not be ignored, nor would flexion/extension alignment. The less constrained the prosthesis, the more important the alignment. Whenever prosthetic constraint is substituted for alignment and ligament balance, stress is transferred to the interfaces and to the prosthetic components. Posterior cruciate substituting prostheses will be less sensitive to flexion instability caused by malalignment, but ignoring flexion stability will produce post wear, and even post fractures have been reported.

**Alignment Issues in TKR**

From the beginning of the history of TKR, alignment has been oversimplified. Interest has focused mainly on varus/valgus alignment,which is mostly what the patient sees.However,the femur can be perfectly aligned with the tibia, and the components can be even severely malaligned. In fact, the most common form of TKR alignment, introduced by Freeman [2] and Insall in the late 1960s and early 1970s, produces minor offsetting malalignments of the femoral and tibial components. This has been referred to as the 'classic' alignment method as opposed to the 'anatomical' alignment method introduced by Hungerford, Kenna, and Krackow. The 'classic' method makes tibial and femoral cuts to place the joint line perpendicular to the mechanical axis.The classic alignment therefore produces a 3° varus malalignment of the femoral component that is offset by a 3° valgus malalignment of the tibial component. These produce a balanced knee in full extension.However the valgus cut on the tibia over-resects the lateral tibial plateau,and this produces lateral instability in flexion. Most systems using the classic alignment system recommend externally rotating the femoral component to compensate for this lateral instability in flexion.Romero et al. compared the consequences of the two alignment systems in normal cadaver knees and found that both systems produce indistinguishable ligament balance throughout the whole range of flexion. There is one particular advantage of the classic system. The tibial cut is perpendicular to the mechanical axis, and therefore a stem attached at 90° to the tibial base plate is lined up with the medullary canal.A long stem attached to a base plate used for an anatomical cut would have to be at 87° to the base plate, and this would necessitate separate components for right and left knees. This is not an issue for most primary knees, since a 90° standard length stem is easily accommodated within the metaphysis.




The tibial resection line is perpendicular to the mechanical axis in the ‘classic’ alignment method of Insall and Freeman, producing over-resection of the lateral plateau. To avoid lateral instability in flexion, the femur must be externally rotated, producing a compensatory sunder-resection of the lateral posterior femoral condyle



**Measured Resection**

The concept of measured resection was introduced by Hungerford, Kenna, and Krackow in 1978 and is currently incorporated to some degree in most instrument systems. The concept involves resecting that amount of the distal and posterior femur that will be replaced by the prosthetic components. Following this concept will place the articular surfaces of the replaced knee at the same level as they were in the natural knee. This is usually possible for a primary total knee replacement,because there is generally at least one intact reference point for both the distal and posterior joint lines. If a normal knee is replaced in this way, the replaced knee functions kinematically identical to the normal knee. Of course, one argument could be that the knee that is a candidate for replacement is not a ‘normal’ knee. However,most of the kinematic abnormalities that afflict the arthritic knee are due to lost cartilage and bone that takes place during the arthritic process. This loss will be replaced through the proper implantation of the prosthetic components and kinematic balance will be restored. The ultimate goal of TKR must include both normal alignment and ligament balance. One without the other is unacceptable.Martin and Whiteside have shown that it is possible to achieve ligament stability in both full extension and 90° of flexion in spite of malpositioning the femoral component proximally and an equal amount anteriorly (theoretically offsetting malalignments) and using a correspondingly thicker tibial spacer. However, doing so produces mid-flexion instability.

**Consequences of Malalignment**

Malalignment has four basic consequences, three due to the overload conditions that are imposed. Interface overload produces aseptic loosening. Plastic overload accelerates wear.Ligament overload produces pain and/or limits motion.Malalignment may also produce instability. However,the importance of the subject to the success of TKR can be illustrated by dissecting the cause of an undesirable finding at the time of trial reduction: lateral patellar subluxation. The ‘knee-jerk’ response to such a finding is to perform a lateral retinacular release and move on.However, unless the patella was subluxing prior to the arthroplasty, something was done during the arthroplasty that has produced this condition, and that ‘something’ should be discovered and corrected.

**Reasons for Patellar Subluxation**

There are nine malalignments that produce patellar subluxation:

- Femoral component malalignment. This comprises internal rotation, medial displacement, and valgus malalignment. These three reorient, or displace the trochlear grove to increase the ‘Q’angle,increasing the tendency toward lateral patellar subluxation.

- Anterior displacement/femoral component oversizing: These both displace the trochlea, and hence the patella, anteriorly, tightening the lateral retinaculum and increasing the tendency toward lateral subluxation.

- Tibial component malalignment. This comprises internal rotation, medial displacement, and valgus malalignment.These three displace the tibial tuberclelaterally, increasing the ‘Q’ angle, and increasing the tendency toward lateral patellar subluxation.

- Patellar component malalignment:

a) Under-resection of the patella displaces the ligament attachment to the patella more anteriorly, tightening the lateral retinaculum and increasing the tendency to lateral subluxation.

b) Lateral displacement of the patellar component laterally displaces the center of the patellar articulating surface, requiring medial translation to interface with the trochlea. This increases the ‘Q’ angle and increases the tendency to subluxation. There is no patellar subluxation in the majority of the knees presenting for replacement. Therefore, if there is patellar subluxation at the end of the procedure,it is more logical to look for a cause rather than simply jump to a lateral retinacular release. Similar circumstances apply to fixed flexion contracture, medial-lateral instability or imbalance,instability in flexion,instability in extension,global instability,and limited flexion. All of the above can be associated with the presurgical pathology, or all of them can be produced by component malalignment. It is the surgeon’s responsibility to eliminate these adverse conditions prior to closing the knee, and in order to do so he/she must understand the origins of the problems, including the possible role of malalignment. Significant malalignment is usually revealed during the trial reduction by imposing the abnormal kinematics that are characteristic of it.

# MATERIALS AND METHODS

This study was an analytical study conducted in Coimbatore medical college in the Institute of Orthopaedics, between the period of July 2016 to September 2018. This study was conducted in adult persons without any pathology in both the knee joints. Detailed history taking and clinical examination including Age, sex, Socio economic status, personal habits, nature of work will be taken. Detailed radiological examination of both the knee joints were carried out in all persons in Orthopaedic out patient department. The radiological assessment included routine anteroposterior and lateral views of the knee joint and a special view, the knealing view of the knee joint.

**EXCLUSION CRITERIA:**

- Skeletally immature individuals
- Individuals with distal femur fracture, supra condylar fracture
- Individuals with malunion of articular fractures of knee
- Osteoarthritis knee with deformities
- Individuals who have undergone previous surgery in distal femur
- Individuals with congenital deformities of distal femur
- Individuals not willing to give consent.

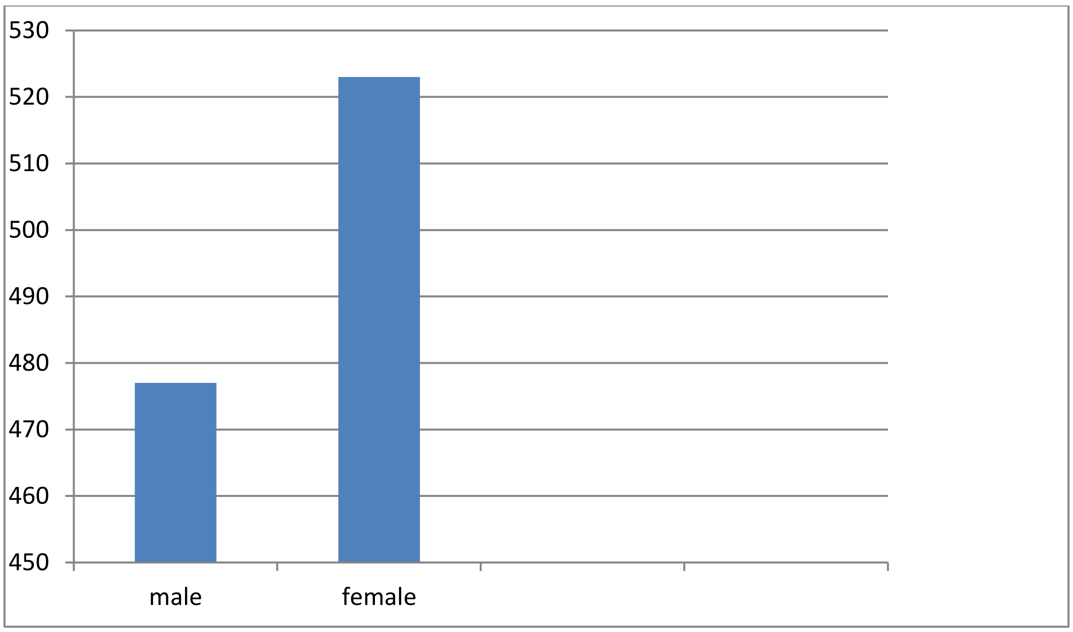
A total of 1000 individuals were included in the study,477 males and 523 females with a mean age of 39 years were studied for a period of 2 years.

**MEASUREMENTS**

It includes the measurements of the

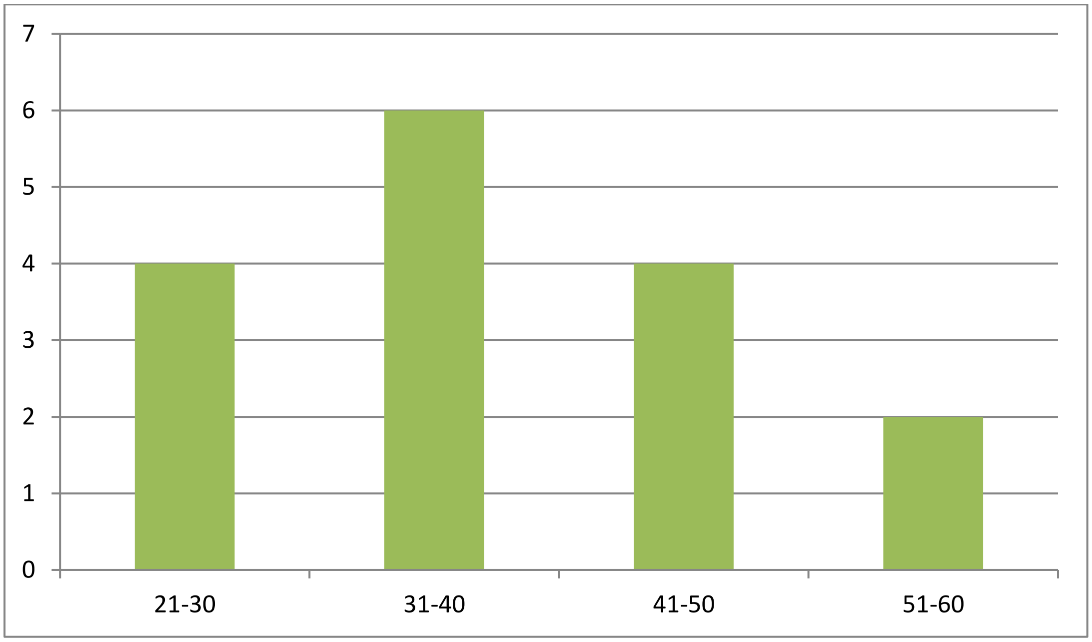
- Distal Femoral Torsion(DFT),
- Anatomic axis, knee alignment
- Blumensaat Line Length (BLL),
- Posterior Distal Femoral Angle(PDFA),
- Blumensaat's line angle,
- Interepicondylar Distance(IED),
- Metaphyseo Diaphyseal Angle(MDA),
- Posterior Tibial Slope(PTS),
- Tibia Plateau Angle,
- Tibial plateau length,
- Tibial plateau width.

**Figure 1: Sex distribution**



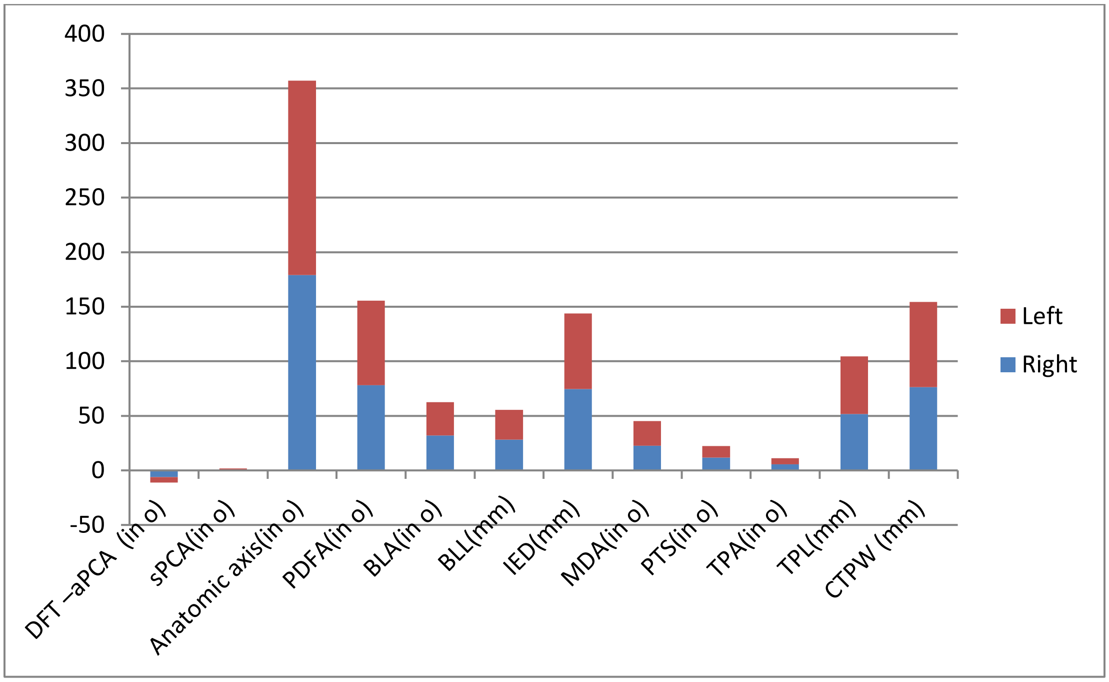

The above chart shows the sex distribution in our study. Majority of the persons were females.

Figure 2: Age distribution

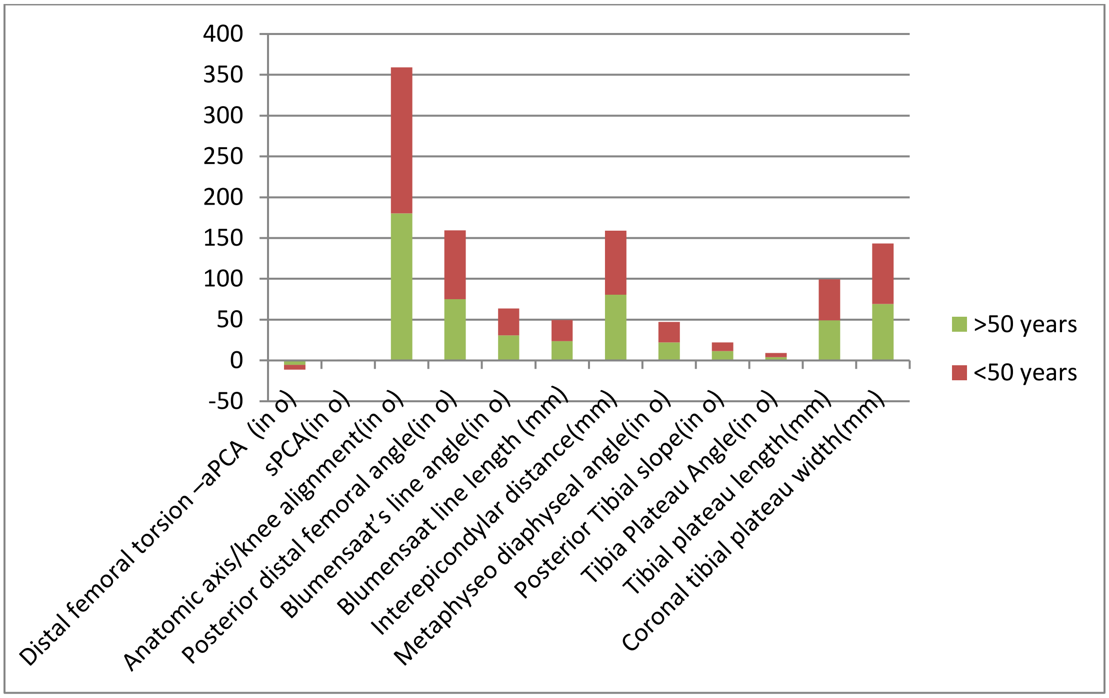



The above chart shows distribution of age of the persons in our study. Majority of the patients were between 31 and 40 years.

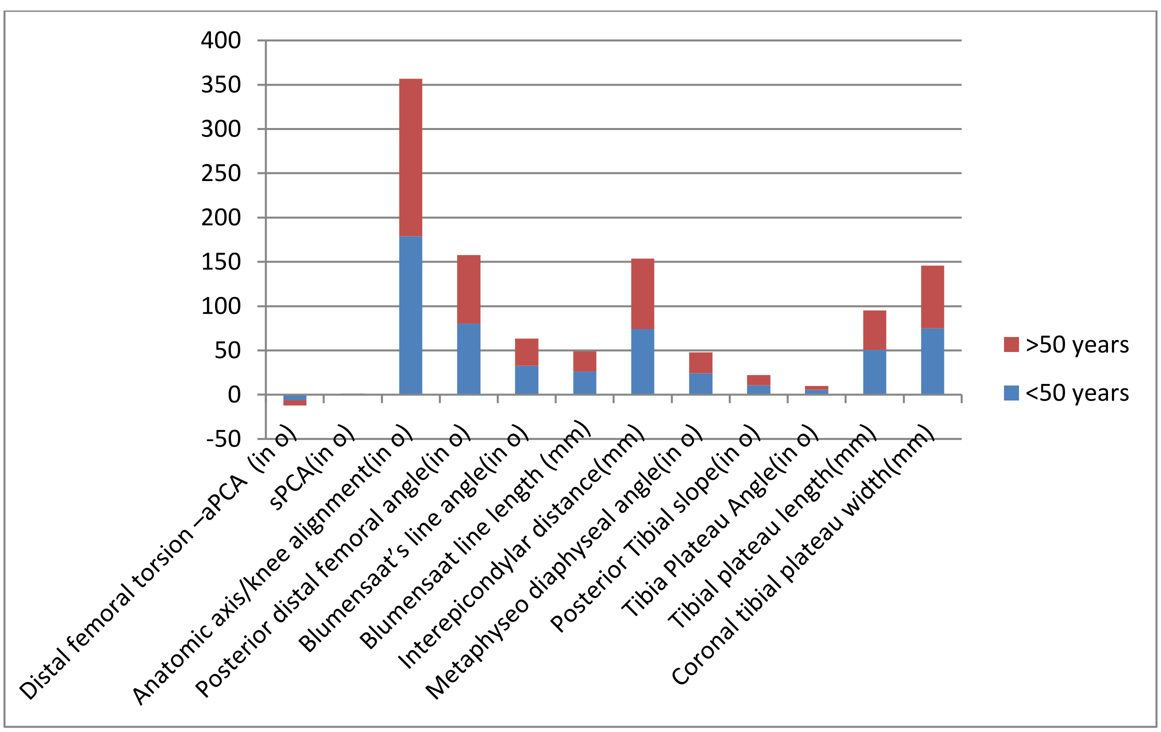
Figure 3: **Distribution with reference to side**



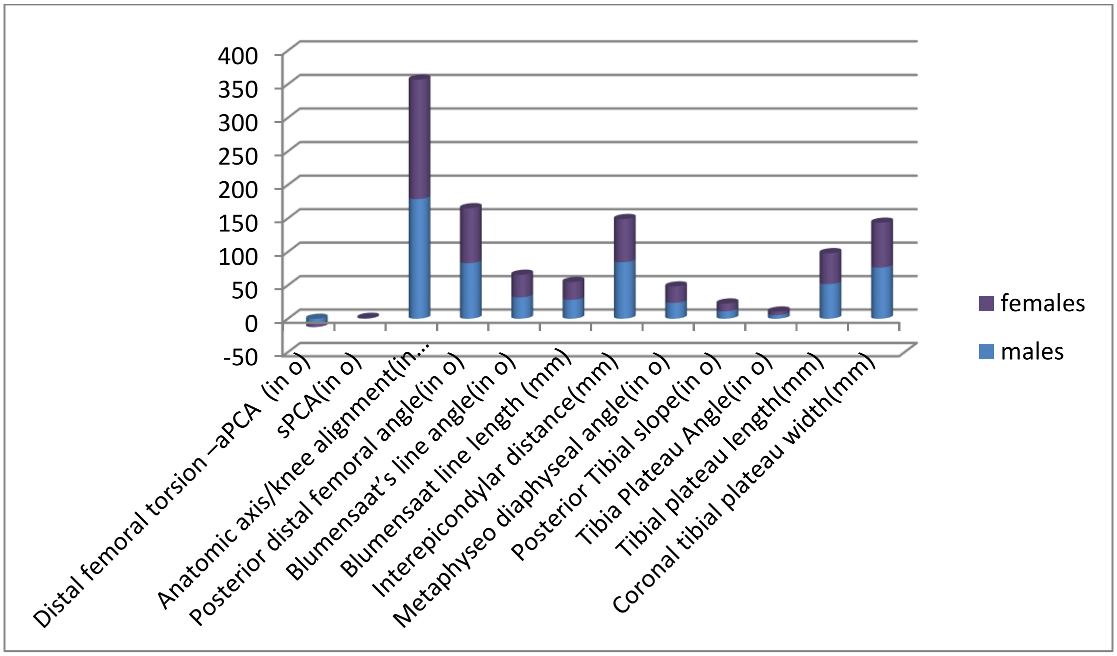
## Distribution with reference to age on the right side



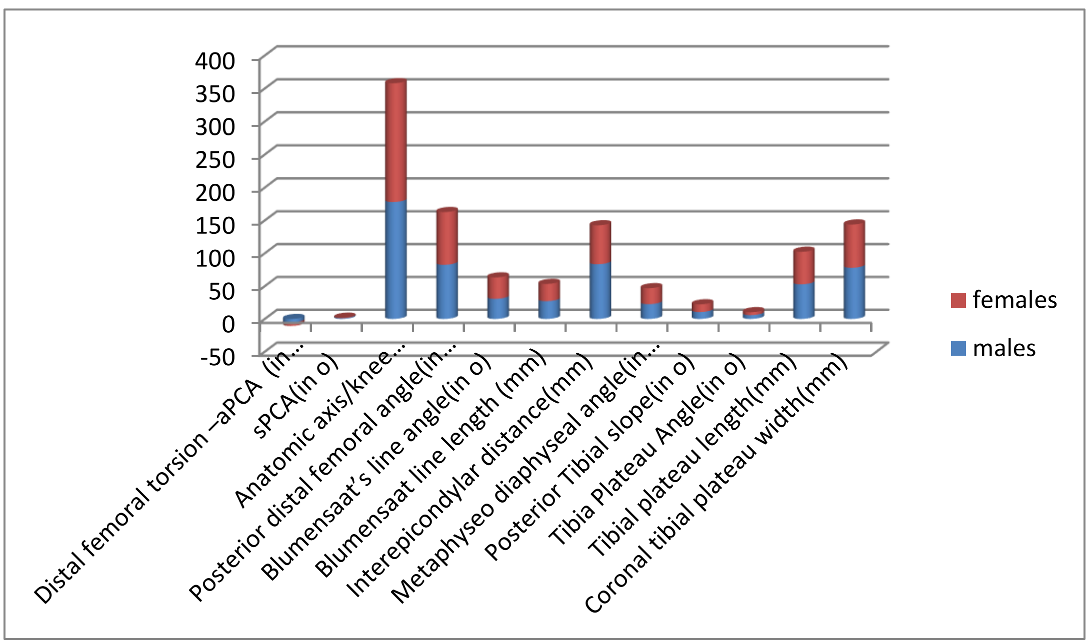

## Distribution with reference to age on the left side



## Distribution with reference to sex on the right side




## Distribution with reference to sex on the left side



## ANALYSIS OF RESULTS

The persons who were included in the study were evaluated for the measurable parameters around the knee joint using digital xrays with anteroposterior, lateral and knealing views. The measurements were compared on both sides.

| Measurements | Right | Left | Range | SD | SEM | p value |
|---|---|---|---|---|---|---|
| Distal femoral torsion-aPCA(in°) | -6.0 | -5.2 | 0- -10 | 1.6 | 0.071 | <0.001 |
| sPCA(in °) | 0.5 | 1.2 | -5 - +2 | 1.4 | 0.062 | <0.001 |
| Anatomic axis/knee alignment (in°) | 179 | 178.1 | 173-185 | 2.1 | 0.093 | 0.452 |
| Posterior distal femoral angle(in°) | 78.1 | 77.4 | 65-91 | 5.6 | 0.160 | 0.06 |
| Blumensaat's line angle(in°) | 32 | 30.6 | 25-38 | 2.6 | 0.116 | <0.001 |
| Blumensaat line length (mm) | 28.3 | 27.1 | 22.7-38.9 | 2.8 | 0.125 | <0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Interepicondylar distance(mm) | 74.5 | 69.3 | 51-108 | 10.5 | 0.469 | <0.001 |
| Metaphyseo diaphyseal angle (in$^o$) | 22.76 | 22.48 | 3-45 | 10.5 | 0.246 | 0.45 |
| Posterior Tibial slope(in$^o$) | 11.64 | 10.82 | 2-21 | 4.5 | 0.201 | <0.001 |
| Tibia Plateau Angle(in$^o$) | 5.5 | 5.8 | 2-9 | 1.5 | 0.067 | <0.001 |
| Tibial plateau length (mm) | 51.8 | 52.7 | 42.4-71.7 | 4.7 | 0.210 | 0.025 |
| Coronal tibial plateau width(mm) | 76.4 | 77.9 | 63.9-94.7 | 6.8 | 0.304 | 0.05 |

These are the measurements obtained in 100 of the 1000 persons in whom significant differences in the measurement of certain values were obtained.

Thus 10% of our study subjects had significant variations in the distal femoral and proximal tibia morphology especially in the distal femoral torsion, blumensaat line angle, blumensaat line length, posterior tibial slope and tibial plateau angle.

| **Measurements** | **Right** | **Left** |
|---|---|---|
| Distal femoral torsion –aPCA (in$^o$) | -6.0 | -5.2 |
| sPCA (in$^o$) | 0.5 | 1.2 |
| Anatomic axis/knee alignment (in$^o$) | 179 | 178.1 |
| Posterior distal femoral angle (in$^o$) | 83.1 | 82.4 |
| Blumensaat's line angle (in$^o$) | 32 | 30.6 |
| Blumensaat line length (mm) | 28.3 | 27.1 |
| Interepicondylar distance (mm) | 84.5 | 83.3 |
| Metaphyseo diaphyseal angle(in$^o$) | 23.76 | 22.48 |
| Posterior Tibial slope (in$^o$) | 11.10 | 10.48 |
| Tibia Plateau Angle(in$^o$) | 5.5 | 5.8 |

| | | |
|---|---|---|
| Tibial plateau length (mm) | 51.8 | 52.7 |
| Coronal tibial plateau width (mm) | 76.4 | 77.9 |

These are the measurements obtained in 477 males who were included in our study.

| Measurements | Right | Left |
|---|---|---|
| Distal femoral torsion –aPCA (in$^o$) | -6.3 | -5.4 |
| sPCA (in$^o$) | 0.8 | 0.6 |
| Anatomic axis/knee alignment(in$^o$) | 177.6 | 179.9 |
| Posterior distal femoral angle(in$^o$) | 82.1 | 80.4 |
| Blumensaat's line angle(in$^o$) | 33.7 | 32.6 |
| Blumensaat line length (mm) | 26.6 | 26.2 |
| Interepicondylar distance (mm) | 64.5 | 59.3 |
| Metaphyseo diaphyseal angle (in$^o$) | 24.45 | 24.28 |
| Posterior Tibial slope (in$^o$) | 11.64 | 11.72 |

| | | |
|---|---|---|
| Tibia Plateau Angle (in°) | 5.2 | 4.4 |
| Tibial plateau length (mm) | 46.2 | 49.6 |
| Coronal tibial plateau width (mm) | 67.1 | 65.9 |

These are the measurements obtained in 523 females included in our study. There were no significant variations among males and females on either side of the knee joint.

# DISCUSSION

A total of 1000 persons were included in this study and evaluated using the digital xray machine available in our institution. All the persons were explained the details of the study and only after getting their consent the study was proceeded. Ethical committee clearance for this study was also obtained from our Institution. The main indication for selection is that the person should not have any gross pathology or deformity of any knee. Adult individuals after skeletal maturity between the ages of 20 and 60 were included in this study.

Although CT remains the reference standard for most of the measurements in this study, several factors limit its use. CT machines are not always widely available, wait times are longer than for standard radio-graphs and cost about five times greater, the technique is nots tandardised,radiation (knee position, settings) is considerably higher (5 to 20 mSv). For a reliable assessment of bony landmarks,the horizontal sections must go through all the landmarks simultaneously. Obstacles to meeting this criterion include knee positioning difficulties (e.g., fixed flexion), presence of metallic artefacts, and severe osteoarthritis with ostephytes. Yoshino et al reported that the medial sulcus was identifiable in only 30% of patients. Similarly, in a studyof 111 knees, Akagi et al identified three types ofmedial sulcus: easily recognisable, *n* = 27; barely recognisa-ble, *n* = 55; and not recognisable, *n* = 29 (26%). Difficulties in identifying bony landmarks were reported in most studies,regardless of the method used . These difficulties may affect the reliability of the measurements. Three-dimensional CT requires additional time to perform the reconstruction and seems to improve neither definition nor measurement reliability.

This study thus makes an honest attempt in measuring all the parameters using digital xrays which carry the advantages of being easily available,affordable and has far less radiation exposure when compared to CT. Moreover the inter observer(98%) and intra observer(95%) reliability is improved because of the standardization done in making the measurements. All the xrays were taken by experienced radiographers from our institution.

The AP, weight-bearing, short knee X-ray was obtained with the patient standing with the back of their knees in contact with the vertical cassette, and the central beam centred 2.5 cm below the apex of the patella with a film to focus distance of 100 cm. The patient was asked to stand with their feet slightly externally rotated, so that the angle between the feet was approximately 15°. All radiographs were obtained with the same technique for each subject.

Radiographs in the current study were obtained with a film-focus distance of 130 cm, 60 kV, 200 mA, and 50 ms. The weight bearing anteroposterior knee radiographs were obtained with the knee fully extended and rotated, with the patella in the center of the femoral condyle. The beam was aligned relative to the joint space and positioned parallel to the floor with no angle. The lateral knee radiographs were obtained with the knee flexed at $55^0$. The beam was aligned relative to the joint space and angled $5^0$ caudally. The kneeling view was taken with the knee in 80° of flexion. The patient kneels on the radiographic film, with the hip in neutral rotation. The X-ray beam is vertical, centred on the popliteal fossa and perpendicular to the tibial shaft.

Anatomical alignment is measured from the AP knee radiographs. A dot is placed at the midpoint of the tibial spines. The femoral anatomical axis is then found by drawing a line from the midpoint of the tibial spines to a point 10 cm above the tibial spines, midway between the medial and lateral femoral cortical bone surfaces. The tibial anatomical axis is found by drawing a line from the midpoint of the tibial spines to a point 10 cm below the tibial spines, midway between the medial and lateral cortical bone surfaces. The medial angle of the intersection of the axes is then measured, with measurements recorded as either >180° or <180° depending on valgus or varus malalignment.

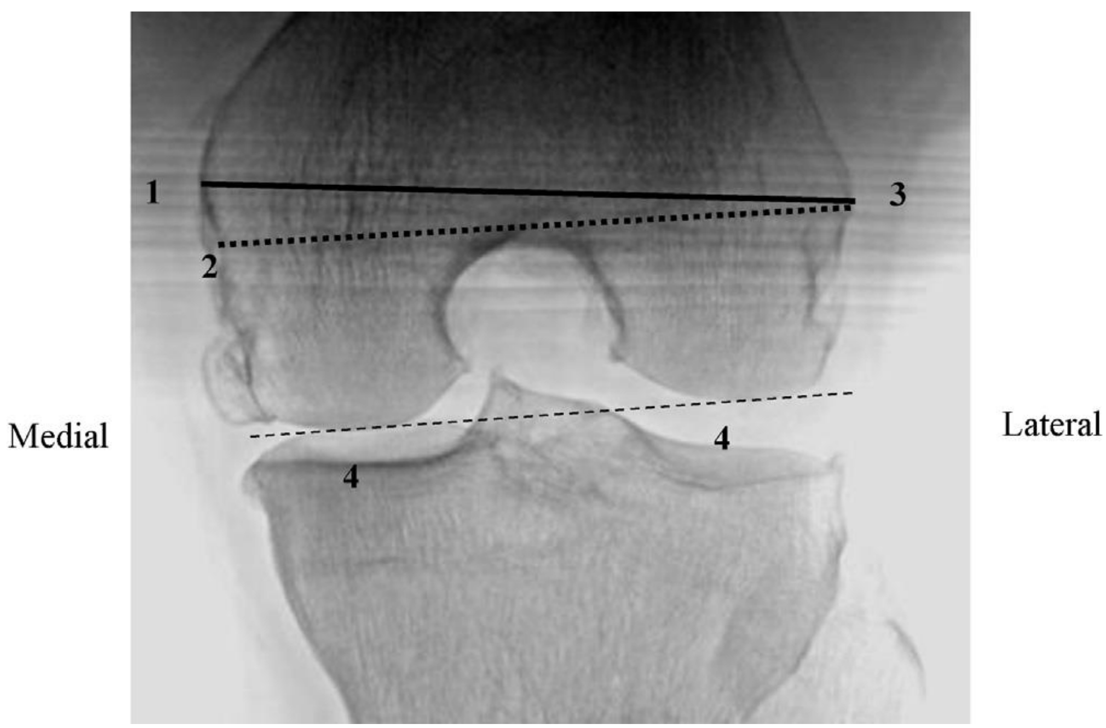
Distal femoral torsion (DFT) is a crucial parameter for knee replacement surgery as it governs knee kinematics,most notably patellar tracking, as well as ligament balance in flexion.

These bony landmarks were used to define two angles (in◦) determining DFT:

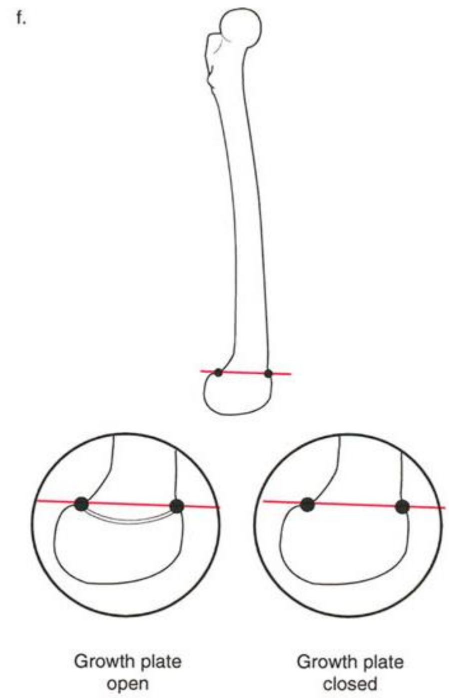
- the aPCA(Anatomic Posterior Condylar Angle) between the tangent line to the posterior condyles and the trans epicondylar axis

- the sPCA(Surgical Posterior Condylar Angle) between the tangent line to the posterior condyles and the line connecting the lateral epicondyle to the medial sulcus of the medial epicondyle.

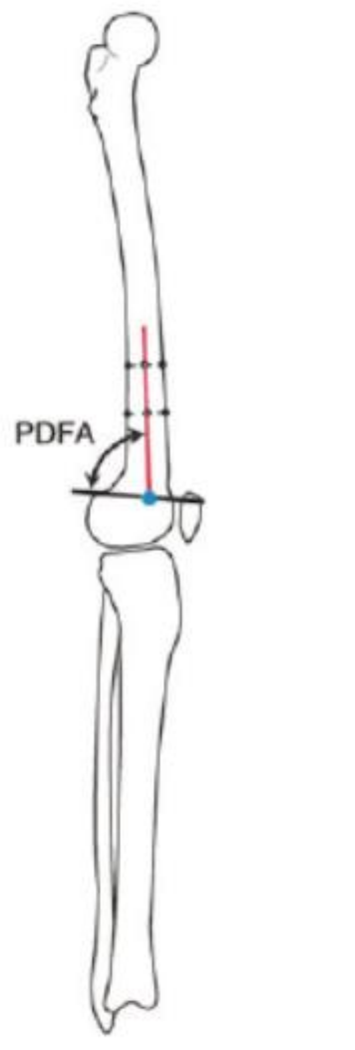
When the tip of the angle pointed laterally, the distal femur was twisted internally and the PCA was arbitrarily reported as negative (anti-clockwise direction for the left knee). When the tip of the angle pointed medially, the dis-tal femur was twisted externally and the angle was positive(clockwise direction for the left knee)



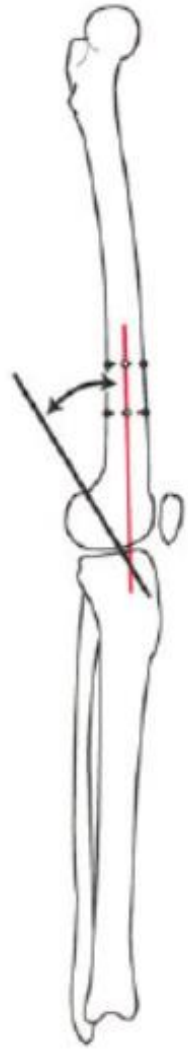
Distal femoral joint orientation line, sagittal plane. Connect the two anterior and posterior points where the condyle meets the metaphysis.



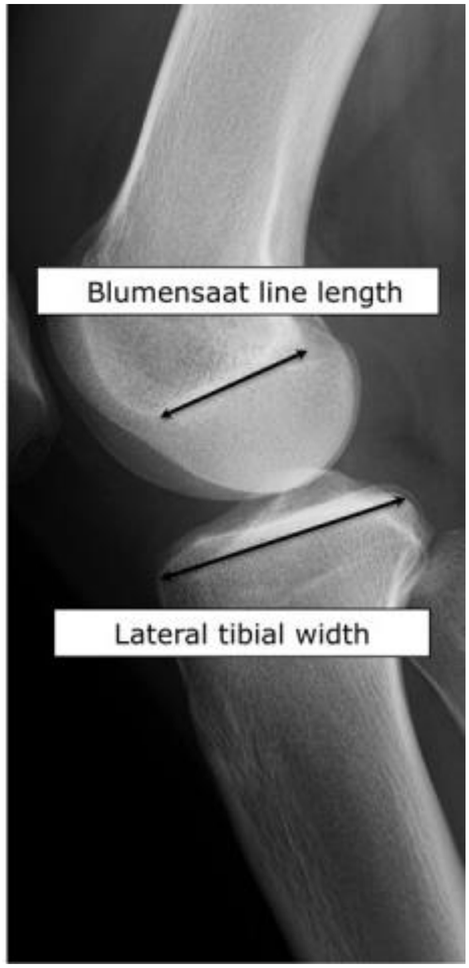

Posterior distal femoral angle is the angle subtended between the distal femur mid diaphyseal line (distal femoral anatomic axis) and the posterior distal femoral angle (PDFA).



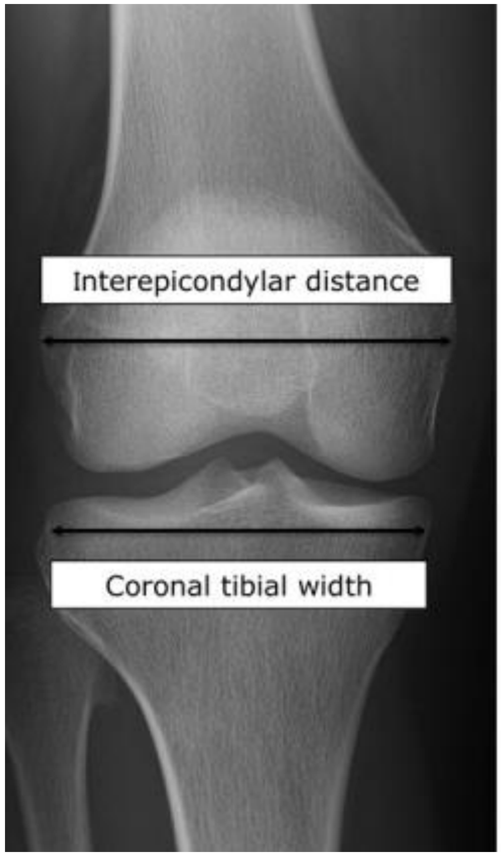

Blumensaat's line angle(BLA) is measured between the Blumensaat's line and the distal femoral anatomic axis.



Blumensaat line represents the roof of intercondylar notch in lateral view xray. On the lateral radiograph, the Blumensaat line length (BLL) and tibial plateau length (lateral tibial width [LTW]) were measured. Tibial plateau size was measured at the level of the subchondral bone.




On the antero posterior radiograph, the distance between the medial and lateral femoral epicondyles (interepicondylar distance [IED]) and the tibial plateau width (coronal tibial width [CTW]) were measured.

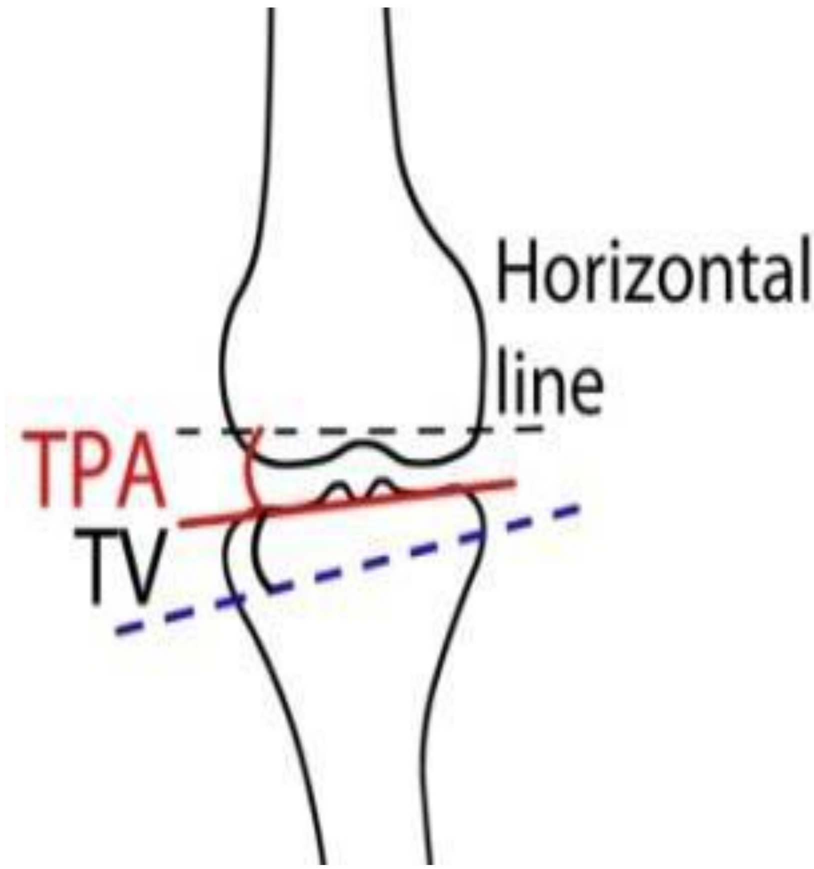



Metaphyseo Diaphyseal Angle(MDA) is the angle formed between two lines: first line is the proximal anatomical axis of the tibia and the second is the axis of the metaphysis. First, in a lateral view radiograph, the proximal anatomical axis of tibia (i.e. the first line) is drawn by connecting midpoints of outer cortical diameter of tibia at 5 and 15 cm distal to the knee joint. Then, the axis of metaphysis (i.e. the second line) was drawn by defining two points each on anterior and posterior cortices of tibial metaphysis in a lateral film and joining the midpoints.Finally, the angle between these two lines (i.e.the MDA) was measured.

Preoperative Posterior Tibial Slope(PTS) was defined as the angle formed by two lines in the lateral radiograph.The first line was the line perpendicular to the anatomical axis of the tibia. The second line formed by joining the most proximal points on the tibia plateau on the lateral radiograph avoiding osteophytes. Although previously, there was no consensus on the ideal anatomical axis to measure PTS, the proximal anatomical axis, i.e. the line connecting midpoints of outer cortical diameter at 5 and 15 cm distal to the knee joint is now recommended because it is most parallel to the sagittal mechanical axis. Hence this axis was assumed to be the anatomical axis in our study.


Line 1
Line 2

Tibia Plateau Angle (TPA) is defined by the angle between proximal tibial articular line and the horizontal.



# CONCLUSION

Our study aimed at evaluating the differences in the morphometric distal femur dimensions between the right and left side of a human subject. The morphometric analysis of proximal tibia were also included later in the study. All the persons included in the study had no significant pathology in and around the knee joint.

- Average age of the persons included in our study was 39 years
- Total of 473 females and 427 males were included in our study
- No significant variations in the measurements were found between males and females in either of the knee joint.
- Significant variations in the distal femoral and proximal tibia morphology especially in the distal femoral torsion, blumensaat line angle, blumensaat line length,posterior tibial slope and tibial plateau angle were found among 10% of the study subjects.

Anatomical variations in the size of the normal knee have been studied, however asymmetry between the two knees has not been studied extensively. Our study is the first to document in detail the asymmetry that exists between the two knees in the South Indian population using digital xrays.

The importance of proper sizing of the components during Total Knee Arthroplasty cannot be overemphasized. An improper sizing of the femoral component can lead to a flexion-extension gap mismatch. A large-sized femoral component can lead to the loss of the flexion space thus leading to the postoperative loss of flexion and also overstuffing of the patellofemoral joint. An undersized femoral component can lead to flexion instability. An improperly sized tibial component can lead to the posterolateral overhang of the implant that can impinge on the popliteus and posterolateral corner.

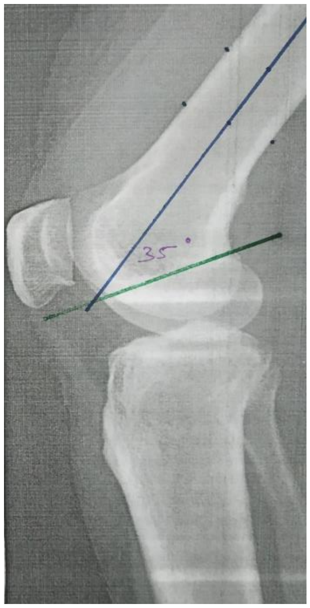
We conclude that the incidence of asymmetry is around 10% and hence we recommend that each knee must be sized independently. Measuring the contralateral knee for choosing the implant on the other side might result in an error of the component size that will result in complications.

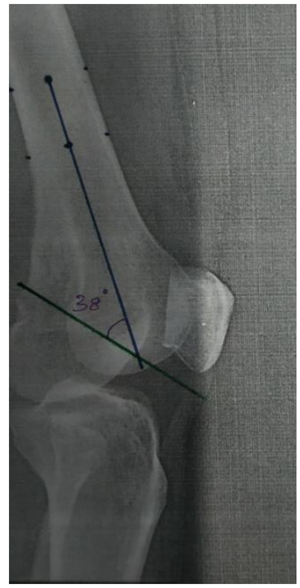
Though computersied tomography is considered as the best method for assessing the component size and also the asymmetry,the radiation exposure and the cost factor makes it a limitation for its availability to the masses. Our study shows that digital xrays can be used to measure the asymmetry that exists between the two knees and limit the use of CT scan for such patients alone.

However the limitations of this study is that it is a single centre study using a homogenous population subset. Large multicentric studies involving heterogenous population subset is required to confirm the findings and to apply the same in future bilateral Total Knee Arthroplasties.

# CASE ILLUSTRATION

Measurement X-rays




BLA

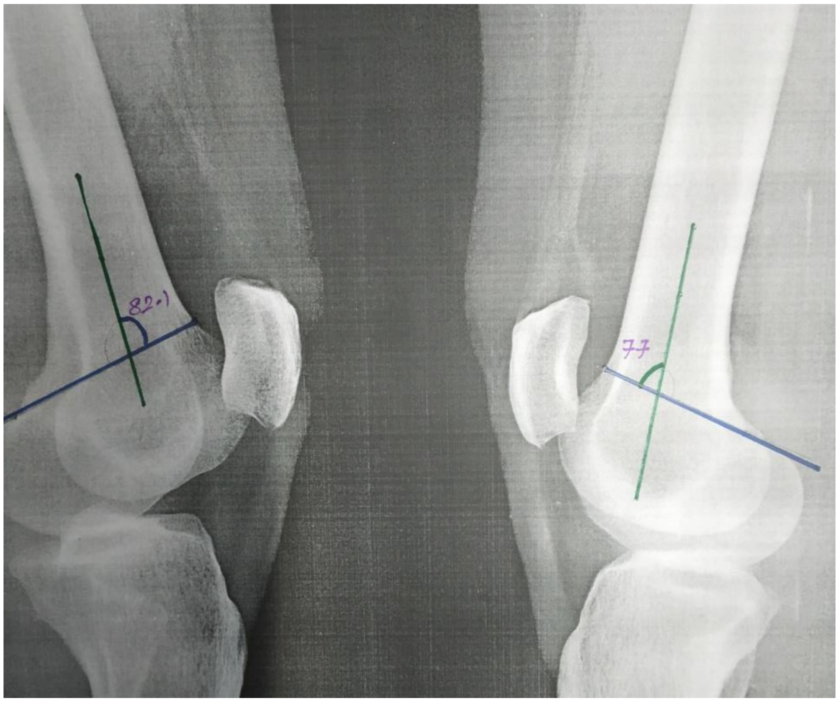

BLL

DFT

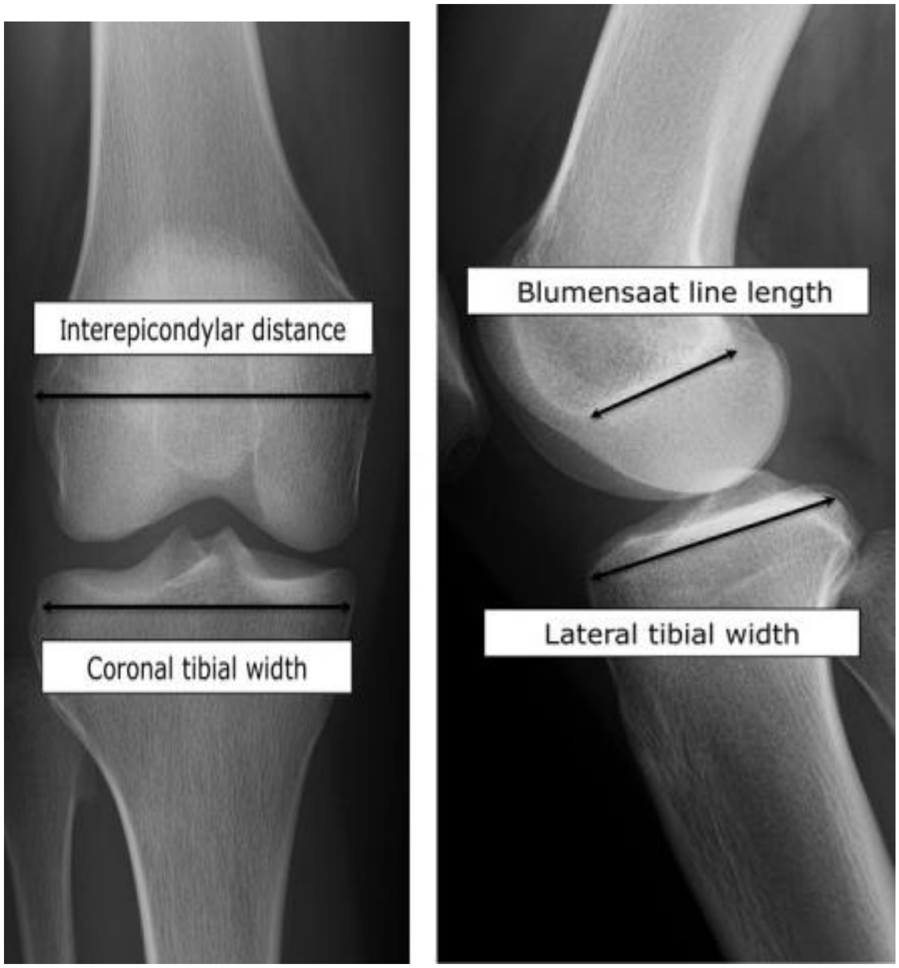

ANATOMIC AXIS


MDA


PTS




PDFA


Interepicondylar distance
Coronal tibial width
Blumensaat line length
Lateral tibial width

# BIBLIOGRAPHY


1. Reddy VG, Mootha AK, Thayi C, Kantesaria P, Kumar RV, Reddy D. Are both the knees of the same size? Analysis of component asymmetry in 289 bilateral knee arthroplasties. Indian J Orthop [serial online] 2011 [cited 2016 Nov 10 ];45:251-254.

2. Alexandra N. Colebatch a,Deborah J.Hart b,Guangju Zhai b, F.M. Williams b,Tim D. Spector b, Nigel K. Arden; A.N Effective measurement of knee alignment using AP knee radiographs ;. Colebatch et al. / The Knee 16 (2009) 42–45

3. Shubhranshu S Mohanty, Nandan N Rao, Kumar K Dash, Sunil K Bhosale .Correlation of posterior tibial slope with metaphysio-diaphyseal angle in total knee arthroplasty: A radiological study; Year : 2013 | Volume : 47 | Issue : 1 | Page : 67-71

4. T. Viel, C. Casin, F. Ducellier, V. Steiger, N. Bigorre, P. Bizot; Is radiographic measurement of distal femoral torsion reliable? 1877-0568– see front matter © 2013 Published by Elsevier Masson SAS http://dx.doi.org/10.1016/j.otsr.2013.02.009

5. Daisuke Chiba,MD, PhD, Eiichi Tsuda,MD, PhD, Shizuka Sasaki,MD, PhD,Xizhe Liu,MD, and Yasuyuki Ishibashi,MD, PhD; Anthropometric and Skeletal Parameters Predict 2-Strand Semitendinosus Tendon Size in Double-

Bundle Anterior Cruciate Ligament The Orthopaedic Journal of Sports Medicine, 5(8), 2325967117720148 DOI: 10.1177/2325967117720148 The Author(s) 2017

6. D. T. Felsony, T. D. V. Cookez, J. Niuy, J. Gogginsy, J. Choiy, J. Yux and M. C. Nevittk. Can anatomic alignment measured from a knee radiograph substitute for mechanical alignment from full limb films? Osteoarthritis and Cartilage (2009) 17, 1448e1452.
7. Rana S. Hinman, Rachel L. May, And Kay M. Crossley. Is There an Alternative to the Full-Leg Radiograph for Determining Knee Joint Alignment in Osteoarthritis? Arthritis & Rheumatism (Arthritis Care & Research) Vol. 55, No. 2, April 15, 2006, pp 306–313 DOI 10.1002/art.21836.
8. Sakeba N. Issa,Dorothy Dunlop,Alison Chang,Jing Song,Pottumarthi V. Prasad,Ali Guermazi,Charles Peterfy,September Cahue,Meredith Marshall,Dipali Kapoor,Karen Hayes,And Leena Sharma. Full-Limb and Knee Radiography Assessments of Varus-Valgus Alignment and Their Relationship to Osteoarthritis Disease Features by Magnetic Resonance Imaging. Arthritis & Rheumatism (Arthritis Care & Research) Vol. 57, No. 3, April 15, 2007, pp 398–406 DOI 10.1002/art.22618.
9. Adrien Durandet, Pierre-Louis Ricci, Amir Hossein Saveh, Qureish Vanat, Bin Wang, Ibrahim Esat, Mahmoud Chizari. Radiographic Analysis of Lower Limb Axial Alignments. Proceedings of the World Congress on Engineering 2013 Vol II, WCE 2013, July 3 - 5, 2013, London, U.K.

10. Vaidya SV, Ranawat CS, Aroojis A, Laud NS (2000) Anthropometric measurement to design total knee prostheses for the Indian population. J Arthroplasty15: 79–85

11. Mihalko W, Fishkin Z, Krackow K. Patellofemoral overstuff and its relationship to flexion after total knee arthroplasty. Clin Orthop Relat Res 2006;449:283-7.

12. Police P, Lotke PA, Lonner JH. Principles of instrumentation and component alignment. In: Callaghan JJ, Rosenberg AA, Rubash HE, Simonian PT, Wickiewicz TL, editors. The adult knee. Philadelphia, PA: Lippincott Williams and Wilkins, 2003. p. 1085-1093

13. Brown TE, Diduch DR, Moskal JT. Component size asymmetry in bilateral total knee arthroplasty. Am J Knee Surg 2001;14:81-4.

14. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;248:13-4.

15. Bo Yang,Jia –Kuo Yu,Zhuo – Zhao Zheng.Comparative study of sex differences in distal femur Morphology in Osteoarthritic knees in a Chinese population.

16. Jess H.Lonner,MD, Jeff G.Jasko,MS, and Beverly S.Thomas.Arthropomorhic differences between the distal femora of men and women.

17. Capaci CM,Brown EC 3rd,AScuderi GR,Scott WN. Component asymmetry in simultaneous bilateral total knee arthroplasty.Journal of arthroplasty 2006 ;21-5 :749-753

18. *Vetrivel Chezian Sengodan, Elangovan Sinmayanantham, J Saravana Kumar*. Anthropometric analysis of the hip joint in South Indian population using computed tomography. IJOrtho_328_15R13.

19. Kirby Hitt,MD;John R.Shurman MD;Kenneth Greene,MD;Anthropometric Mesurements of the Human Knee:Correlation to the Sizing of current Knee Arthroplasty systems.2003;85(suppl 4):115-122.

20. Kanekasu K, Kondo M, Kadoya Y. Axial radiography of the distal femur to assess rotational alignment in total knee arthroplasty. Clinical orthopaedic relat res 2005;434:193-197

21. Robert W.W. M.D.; Himeno, shlnkichl M.D.;Conventry, Mark B M.D.;Chao. Normal axial alinment of the lower extremity and load-bearing distribution at the knee. Clinical orthopaedics and related research 1990.

22. Cheng FB, Ji XF, Lai Y, Feng JC, Zheng WX, et al. (2009) Three dimensional morphometry of the knee to design the total knee arthroplasty for Chinese population. Knee 16: 341–347 Conley S, Rosenberg A, Crowninshield R (2007) The female knee:

23. Guy SP, Farndon MA, Sidhom S, Al-Lami M, Bennett C, et al. (2012) Gende differences in distal femoral morphology and the role of gender specific implants in total knee replacement: a prospective clinical study. Knee 19: 28–31.

24. Shinro Takai MD,nobuyuki Yoshino A new roentgenographic technique to assess rotational deformity and alignment of the distal femur.Journal of arthroplasty 2003;18-4:478-483

25. Abdul Ghani, Padmaja Kypa, Vasudevan Thirumala Selvan. Difference between right and left side in total knee and unicondylar knee replacement:An interesting observation. Online journal Health Allied Scs 2004;4-3

26. Lonner JH, Jasko JG, Thomas BS (2008) Anthropomorphic differences between the distal femora of men and women. Clin Orthop Relat Res 466: 2724–2729.

# PROFORMA

S.NO:

Patient details

| | |
|---|---|
| Name:<br>Sex: M/F/TG | Age |
| Occupation: | OP/IP no: |
| Address:<br>Contact no: | |
| Unit:<br>Professor: | |
| Date of review: | |
| Clinical history:<br><br>Presenting complaints: | |

RADIOLOGICAL EVALUATION

| Xray both knees AP AND LATERAL views |
| --- |

MEASUREMENTS

| S.No | Measurements | Right | Left |
| --- | --- | --- | --- |
| 1. | Distal femoral torsion –aPCA (in $^{o}$) | | |
| 2. | sPCA(in $^{o}$) | | |
| 3. | Anatomic axis/knee alignment(in $^{o}$) | | |
| 4. | Posterior distal femoral angle(in $^{o}$) | | |
| 5. | Blumensaat's line angle(in $^{o}$) | | |
| 6. | Blumensaat line length (mm) | | |
| 7. | Interepicondylar distance(mm) | | |
| 8. | Metaphyseo diaphyseal angle(in $^{o}$) | | |
| 9. | Posterior Tibial slope(in $^{o}$) | | |
| 10. | Tibia Plateau Angle(in $^{o}$) | | |
| 11. | Tibial plateau length(mm) | | |
| 12. | Coronal tibial plateau width(mm) | | |

# MASTER CHART

| S.NO | NAME | AGE | SEX | OP NO | SIDE | a PCA | s PCA | ANAT AXIS | PDFA | BLA | BLL | IED | MDA | PTS | TPA | TPL | CTPW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MARIA | 28 | F | 465782 | RIGHT | -6.1 | 0.8 | 177 | 82.1 | 31 | 28.3 | 84.5 | 22.76 | 10.1 | 5.4 | 51.8 | 75.4 |
| | | | | | LEFT | -6 | 0.6 | 178 | 83.1 | 32 | 28.3 | 84 | 23.76 | 11 | 5.1 | 50.8 | 76.7 |
| 2 | RAJESH | 41 | M | 478534 | RIGHT | -6.2 | 0.5 | 176.4 | 83.6 | 30.4 | 28.3 | 84.5 | 24.76 | 11.7 | 5.2 | 51.8 | 74.4 |
| | | | | | LEFT | -6 | 0.5 | 180 | 80.1 | 32 | 28.3 | 84.1 | 23.61 | 11.4 | 5.1 | 54.3 | 73.4 |
| 3 | AMUTHA | 33 | F | 543900 | RIGHT | -6 | 0.7 | 179 | 82.45 | 32.8 | 28.3 | 83.5 | 21.76 | 11.1 | 5.5 | 51.7 | 72.4 |
| | | | | | LEFT | -6 | 0.8 | 179 | 81.9 | 32.3 | 28.3 | 80.5 | 23.76 | 10.1 | 5.5 | 51.8 | 71.4 |
| 4 | KANNAN | 49 | M | 553897 | RIGHT | -6 | 0.5 | 177 | 81.1 | 32 | 28.3 | 84.5 | 20.76 | 10.5 | 5.6 | 51.6 | 76.5 |
| | | | | | LEFT | -5 | 0.4 | 177.5 | 83.1 | 32.1 | 28.3 | 81.5 | 21.36 | 11.4 | 4.6 | 51.8 | 76.4 |
| 5 | KRISHNA | 22 | M | 566324 | RIGHT | -6 | 0.5 | 176.5 | 80.65 | 30.6 | 28.3 | 80.5 | 22 | 11.1 | 5.5 | 51.8 | 76.1 |
| | | | | | LEFT | -6 | 0.1 | 179 | 83.1 | 32 | 28.3 | 84.5 | 20.86 | 11.2 | 5.5 | 57.4 | 77.4 |
| 6 | LAKSHMI | 47 | F | 610463 | RIGHT | -6.3 | 0 | 179 | 81.1 | 31.2 | 28.3 | 81.9 | 23.76 | 10.6 | 5.6 | 51.8 | 76.4 |
| | | | | | LEFT | -6 | 0.5 | 175 | 83.24 | 30.9 | 28.3 | 84.5 | 23.76 | 9.1 | 6 | 50.8 | 76.4 |
| 7 | KUMAR | 53 | M | 622387 | RIGHT | -6 | 0.5 | 175.6 | 82.1 | 32 | 28.3 | 84.1 | 23.76 | 12.6 | 5.5 | 51.5 | 69.4 |
| | | | | | LEFT | -6.1 | 0 | 178 | 83.3 | 32.2 | 28.3 | 84.2 | 23.76 | 12.1 | 4.9 | 53.8 | 76.4 |
| 8 | KOKILAVANI | 31 | F | 706887 | RIGHT | -6 | 0.4 | 179 | 83.3 | 30.7 | 28.3 | 82.5 | 21.76 | 10.1 | 5.5 | 51.8 | 76.4 |
| | | | | | LEFT | -6.2 | 0.5 | 177 | 81.5 | 30.6 | 28.3 | 84.5 | 20.04 | 10.2 | 5 | 54.8 | 78.4 |
| 9 | RAMAN | 53 | M | 714356 | RIGHT | -6 | 0 | 179 | 83.5 | 32 | 28.3 | 83.5 | 23.76 | 11.1 | 5.5 | 51.8 | 76.4 |
| | | | | | LEFT | -5.2 | 0.1 | 178 | 83.9 | 30.3 | 28.3 | 86.5 | 23 | 10.1 | 5.6 | 50.7 | 70.4 |
| 10 | MAHESWARI | 40 | F | 747822 | RIGHT | -6.4 | 0.2 | 179 | 83.1 | 32 | 28.3 | 80.5 | 23.78 | 11.1 | 5.3 | 50.2 | 76.4 |
| | | | | | LEFT | -6 | 0.5 | 175.7 | 85.1 | 31.1 | 28.3 | 80.6 | 23.76 | 10.7 | 5 | 51.8 | 76.4 |
| 11 | PALANI | 45 | M | 785641 | RIGHT | -5.7 | 0.7 | 178 | 83.1 | 32.5 | 28.3 | 84.5 | 22.78 | 11.1 | 4.7 | 50.8 | 76.4 |
| | | | | | LEFT | -5.8 | 0.5 | 177 | 80.95 | 33 | 28.3 | 81.7 | 21.06 | 9.3 | 5.5 | 51.8 | 76.4 |
| 12 | KUMARAPAN | 33 | M | 834521 | RIGHT | -6 | 0.5 | 179 | 84.2 | 32 | 28.3 | 80.2 | 21.66 | 9.1 | 4.5 | 51.8 | 71.4 |
| | | | | | LEFT | -6.5 | 0.6 | 179 | 80.9 | 30.6 | 28.3 | 84.5 | 23.76 | 11.1 | 5.9 | 55.9 | 76.4 |
| 13 | CHINNAN | 42 | M | 845621 | RIGHT | -5.9 | 0.5 | 179.1 | 80.14 | 30 | 28.3 | 82.2 | 22.7 | 11.1 | 5.5 | 51.8 | 73.4 |
| | | | | | LEFT | -6 | 0.6 | 175.8 | 80.5 | 30.4 | 28.3 | 84.5 | 23.76 | 11.8 | 5.3 | 55.5 | 73.8 |
| 14 | MERCI | 30 | F | 885421 | RIGHT | -5.5 | 0.5 | 179 | 80.1 | 30.9 | 28.3 | 84.1 | 21.76 | 11.1 | 5.5 | 51.8 | 76.4 |
| | | | | | LEFT | -5.4 | 0.4 | 179.2 | 83.1 | 32 | 28.3 | 84.5 | 23.76 | 11.4 | 5.5 | 53.5 | 76.4 |
| 15 | JANSI | 38 | F | 900233 | RIGHT | -6 | 0.5 | 178 | 84.5 | 31.8 | 28.3 | 82.5 | 23.21 | 10.8 | 4.1 | 52.8 | 77.4 |
| | | | | | LEFT | -5 | 0.3 | 179 | 83.1 | 31.4 | 28.3 | 83.6 | 22.76 | 11.1 | 4.9 | 51.8 | 76.4 |
| 16 | VANI | 45 | F | 1003211 | RIGHT | -6 | 0.2 | 179.4 | 86.1 | 31 | 28.3 | 84.5 | 23.76 | 10.1 | 5.5 | 53.8 | 76.4 |
| | | | | | LEFT | -6 | 0.5 | 179 | 83.1 | 32 | 28.3 | 83.9 | 23.06 | 11.1 | 4.8 | 51.8 | 72.9 |
| 17 | THIMMATHAL | 51 | F | 100651 | RIGHT | -6.4 | 0 | 178.2 | 82.4 | 32.1 | 28.3 | 83.7 | 23.76 | 10 | 4.5 | 51.2 | 76.4 |
| | | | | | LEFT | -5 | 0 | 179.1 | 82.4 | 32.5 | 28.3 | 84.5 | 23.75 | 10.9 | 4.6 | 51.1 | 75.7 |

# ANNEXURE IV

ஒப்புதல் படிவம்

பெயர் :

வயது :

பாலினம் :

முகவரி:

கோவை அரசு மருத்துவக்கல்லூரி மருத்துவமனையில் மருத்துவர் பொன் சென் சூர்யா தலைமையில் நடைபெறும் “இரண்டு முழங்காலிலும் எக்ஸ் ரே கதிர் மூலம் தொடை எலும்பின் கடைப்பகுதி அளவைக் கணக்கிடும்” ஆய்வில் முழு சம்மதத்துடன் கலந்துகொள்ள சம்மதிக்கிறேன். இந்த ஆய்வில் என்னைப் பற்றிய விவரங்களை பாதுகாப்புடன் வெளியிட ஆட்சேபணை இல்லை என்று தெரிவித்துக் கொள்கிறேன். எந்த நேரத்திலும் ஆய்வில் இருந்து விலகிக்கொள்ளும் உரிமை உண்டு என்று அறிவேன்.

# ABBREVIATIONS

- TKA-  Total Knee Arthroplasty
- DFT- Distal Femoral Torsion
- a PCA- Anatomic Posterior Condylar Angle
- s PCA- Surgical Posterior Condylar Angle
- PTS- Posterior Tibial Slope
- PDFA- Posterior Distal Femoral Angle
- BLL – Blumensaat Line Length
- BLA- Blumensaat Line Angle
- IED- Inter Epicondylar Distance
- LTW- Lateral Tibial Width
- CTW- Coronal Tibial Width
- MDA- Metaphyseo Diaphyseal Angle
- TPA-Tibial Plateau Angle