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Original Research Paper

Biomechanical and radiological considerations for correction of varus deformity in primary osteoarthritis during total knee arthroplasty

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Abstract

Background: Total knee arthroplasty (TKA) has proven to be a reliable method of treatment for osteoarthritis (OA). Restoration of lower limb alignment after TKA within $\pm 3^\circ$ of neutral ensures equal load distribution on the medial and lateral compartments which is essential for implant longevity. This study describes biomechanical and radiological considerations for correction of varus deformity in primary osteoarthritis during TKA.

Methods: This is a retrospective study from January 2017 to January 2019 done in Department of Orthopaedics, Grant Medical Foundation- Ruby Hall Clinic, Pune. A radiological study of 20 patients suffering from primary osteoarthritis of knee joint with varus deformity more than 15° who underwent Total Knee Arthroplasty was done. Xrays/Scanograms were evaluated pre operatively and immediate post replacement.

Keywords: Total knee arthroplasty, knee osteoarthritis (OA), varus deformity, mechanical axis of knee

Introduction

Total knee arthroplasty (TKA) has proven to be a reliable method of treatment for severe arthritis of the knee with successful clinical and functional outcomes at long-term. Primary osteoarthritis (OA) remains the most common indication for TKA [6]. It commonly results in a varus deformity since the weight-bearing axis of the lower limb passes medial to the center of the knee. Restoration of lower limb alignment after TKA within $\pm 3^\circ$ of neutral ensures equal load distribution on the medial and lateral compartments which is essential for implant longevity. [10] Deformity in OA at the level of the knee joint is a result of progressive cartilage wear, which in advanced cases may be accompanied by bone loss. This is commonly associated with contracture of the soft tissues on the medial side of the knee in varus deformities. Extra-articular factors like femoral bowing and varus medial proximal tibial inclination may also contribute to the overall varus lower limb alignment.

Though, the lower limb alignment is a result of both articular and extra-articular deformities, it is often possible to restore it within $\pm 3^\circ$ of neutral by correcting the deformity at the joint level. Special circumstances which preclude complete deformity correction at the joint level and ways to manage them are discussed. This study describes the routinely used practices for varus deformity correction during TKA.

Materials and Methods: This is a retrospective study from January 2017 to January 2019 done in Department of Orthopaedics, Grant Medical Foundation- Ruby Hall Clinic, Pune. A radiological study of 20 patients suffering from primary osteoarthritis of knee joint with varus deformity more than 15° who underwent Total Knee Arthroplasty was done. Xrays/Scanograms were evaluated pre operatively and immediate post replacement.

Inclusion criteria

1. Primary osteoarthritis of knee joint with varus deformity more than 15° .

Exclusion criteria

1. Patients suffering from valgus deformity and varus less than 15°
2. Hip and ankle pathologies.
3. Old fractures of tibia/femur with implant in situ.
4. Ongoing knee joint infection.

Pre operative radiological evaluation of mean tibio-femoral angle (Mean varus deformity before TKA)

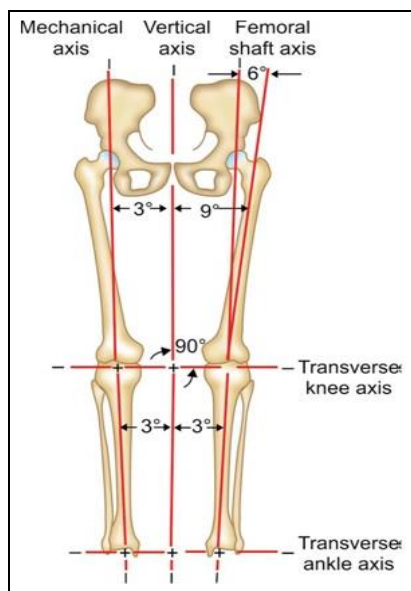
The mean varus deformity of all the patients was analysed through Xray/Scanogram before the total knee arthroplasty. Table 1.

Table 1: Radiological evaluation

Radiological evaluation	Mean tibio-femoral angle (Mean varus deformity)
Pre-Op	17.10°

Understanding the mechanical axis of knee joint

The mechanical axis of the lower limb is the line joining center of the hip joint to the center of the ankle joint and normally passes through the center of the knee joint (Fig. 1).

**Fig 1:** Mechanical axis of the lower limb

In a well-aligned normal knee, both medial and lateral knee compartments get loaded almost equally. Such knee has equal distribution of forces over both knee compartments and as a result is less likely to wear due to mechanical reasons.

In varus deformity, medial compartment of the knee gets loaded excessively and is a major contributing factor leading to medial compartmental arthritis. Normal tibia has 3° of physiological varus as the mechanical axis is at 3° to the vertical axis (Fig.1). The aim of TKA is to have a pain-free, mobile knee that is stable. Following points should be always considered while performing TKA:

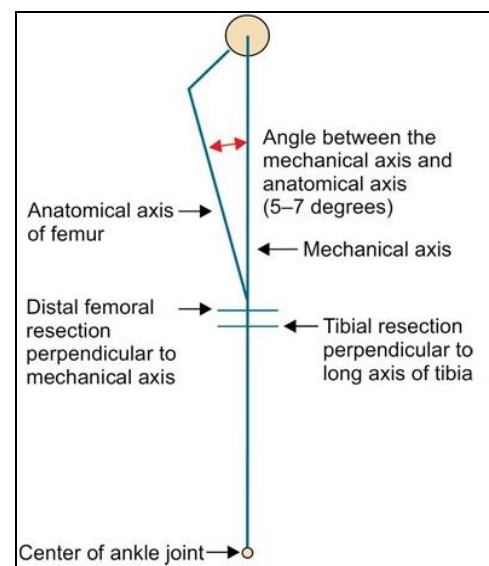
- A. Mechanical axis restoration:** To achieve normal mechanical axis wherein the line passing from center of hip to the ankle joint passes through the center of knee. This will ensure even load distribution over the tibial polyethylene.
- B. Which will reduce wear.** Correction of deformity: The knee can have deformity in any of the three planes. The varus is the commonest deformity, other common deformities include valgus and flexion deformity.

Correction of the deformity restores the normal biomechanics of the knee and improves the survival of the prosthesis.

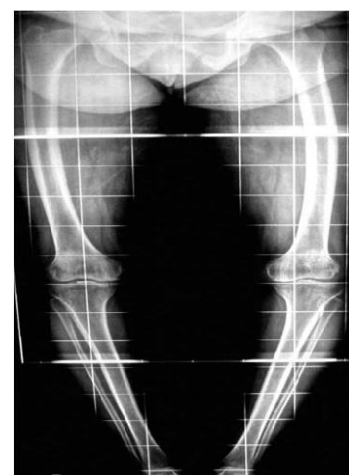
- C. Mediolateral balance:** The medial and lateral stabilizing structures have to be balanced for stability through the range on motion of the knee. The structures that are contracted on the concave side of the deformity need to be released and elongated, to balance with the structures on the convex side of the deformity.

Surgical considerations of mechanical axis

The mechanical axis can be considered to have three segments: (1) Femoral part, (2) intra-articular part, and (3) tibial part. The surgical procedure aims to get this mechanical axis correct. The distal femoral resection is at right angles to the mechanical axis. Most instrumentation systems use medullary canal as reference guide (anatomical axis of femur) and therefore, the angle between the medullary canal axis (anatomical axis) and the mechanical axis can be adjusted and set during surgery for distal femoral resection. In general this ranges from $5-7^\circ$ (Fig. 2).

**Fig 2:** Surgical consideration of mechanical axis

A long leg standing scanogram that shows hip, knee and ankle in anteroposterior (AP) view in one picture allows measurement of this resection angle to be set on the jig (Fig. 3) and measurement of deformity (Fig. 4).

**Fig 3:** Scanogram of hip, knee and ankle in AP view allows measurement of resection angle to be set in the jig

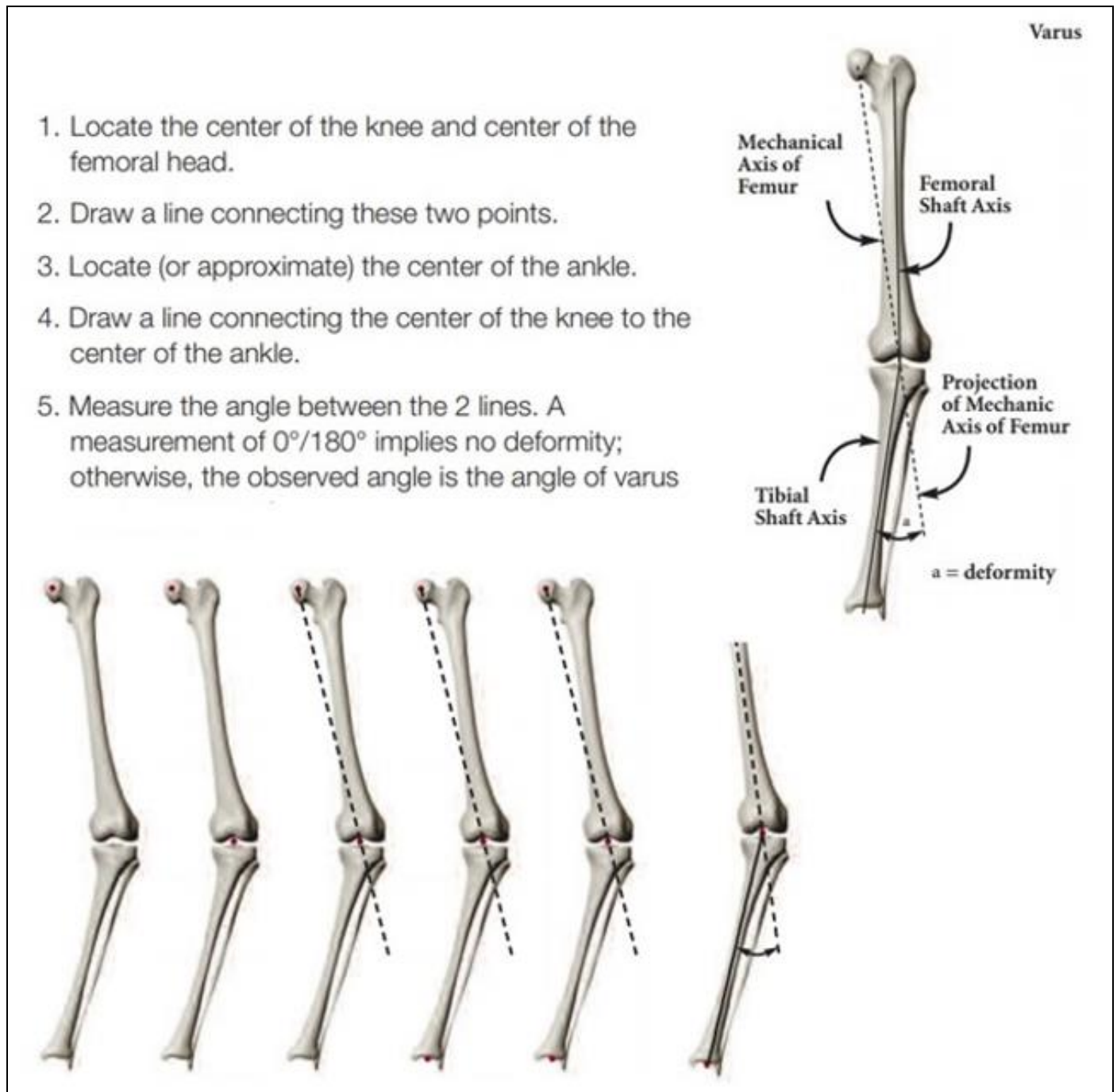


Fig 4: Measurement of Deformity

Tibial resection is perpendicular to the long axis of tibia with center of the tibial plateau and center of ankle joint being the two reference points. Center of tibial plateau is fairly easy to localize and usually is the point just medial to the lateral tibial eminence. The center of the ankle joint is medial to the mid malleolar point as lateral malleolus is placed posterolaterally. Most instrumentation systems have an ankle clamp that allows the adjustment mediolaterally. If the tibial resection is to be done with a posterior slope demanded by the implant design, it is important to align the rotation of the jig to junction of central and medial third of the tibial tubercle. Once the distal femoral resection and tibial resection is done perpendicular to the mechanical axis, extension gap balancing restores the mechanical axis. So balancing and alignment have to be considered complimentary to each other. Basic

bony cuts to create extension and flexion gaps: The three primary bony cuts are:

1. Distal femoral cut
2. Proximal tibial cut
3. Posterior femoral condylar cuts.

All other femoral cuts are necessary to accommodate the femoral component fit on the distal femur. These cuts include anterior cut, anterior and posterior chamfer cuts and the box cut for peg-cam mechanism in PS prosthesis.

As a result of these cuts, the gap created is assessed in two positions

- a. Extension gap: Assessed in full extension(Image 1), and
- b. Flexion gap: Assessed at 90° flexion



Image 1: Extension Gap

The basic aim is to get both extension and flexion gaps rectangular, equal and balanced. The distal femoral cut influences only the extension gap, the posterior femoral condylar cuts influence only the flexion gap while proximal tibial cut influences both extension and flexion gaps. After the distal femoral and proximal tibial resections are done perpendicular to the mechanical axis, extension gap balancing is done depending on the deformity and the tight structures. The posterior femoral condylar cuts can vary, depending on the femoral sizing and the rotation of the femoral component. Rotation of the femoral component largely influences the flexion gap balancing. It is useful to distract the joint in flexion to visually assess the flexion space, prior to posterior resection.

Balance and stability of a normal Knee Joint

Normal knee has certain degree of mediolateral laxity that is necessary to have free motion. In terminal extension, there is no mediolateral laxity and no distraction between medial or lateral joint surfaces is possible. In this position, posterior capsule along with medial and lateral structures are tight. At about 10° flexion and onwards, posterior capsule is relaxed and only medial and lateral structures provide mediolateral stability. Medially, medial collateral ligament provides stability in both flexion and extension, with posterior fibers being tight in extension and anterior fibers being tight in flexion. The lateral stability is provided by multiple structures and is a lot more dynamic depending on the position of flexion. The lateral collateral ligament extends from lateral epicondyle, which is a knuckle shaped structure over lateral femoral condyle about 30 mm from the joint line. The lateral collateral ligament diverts away from the lateral femoral epicondyle to insert in the fibular head with no attachment to tibia. The iliotibial tract provides lateral stability only from full extension to about 30° of flexion, beyond which it ceases to provide stability laterally. Popliteus is an important lateral stabilizer in flexion.

All knee deformities that are not correctable passively have a significant element of soft tissue contracture, with tissues on the concave side of the deformity being contracted and tissues on the convex side being stretched to varying degrees.

Techniques for correction of varus deformity

The primary step is to assess whether the deformity is correctable or not. If the deformity is fully correctable, no significant medial release is necessary and minimal medial subperiosteal release is done to allow forward subluxation of tibia. If the deformity is not correctable, graduated medial release is necessary. The initial medial dissection is subperiosteal and includes release of capsule on the posteromedial corner of tibia along with deep part of medial

collateral ligament. Pes anserinus tendon insertions are usually not released and the superficial medial collateral ligament (MCL) insertion is released over only the proximal 3 cm of tibia at this stage. The extent of proximal tibial bony resection needs to be reduced if there is any stretching of lateral structures as indicated by the lateral compartment distraction on weight bearing AP X-ray. Medial femoral condyle is affected in severe varus deformities. Determination of the divergence angle on preoperative standing scanogram gives an indication of soft tissue releases that may be required for obtaining a neutral lower limb alignment. It is an angle subtended between the level of distal femoral and proximal tibial cuts, which are perpendicular to the femoral and tibial mechanical axes, respectively. Examination of the knee under anesthesia will provide an idea about correctability of the deformity. The knee joint is exposed using any preferred approach. Depending upon the severity of deformity, all or some of the following steps may be necessary to attain the final aim of the procedure i.e.

- A neutral lower limb alignment (collinearity of the centers of hip, knee and ankle or hip-knee-ankle angle = 180°),
- A mediolateral soft tissue gap difference of less than 1 mm in full extension and less than 2 mm at 90° flexion, and
- A flexion-extension gap difference not exceeding 2 mm. Once the extension gap is made after the resection of distal femur and proximal tibia, the balance is checked using rectangular spacer blocks. There should be approximately 1–2 mm opening on both medial and lateral sides on application of varus and valgus stress ^[10]

At this stage, if there is tightness on medial side, one needs to employ the following techniques that can achieve balancing without having to release the superficial medial collateral ligament completely:

- **Removal of osteophytes on the medial femoral and medial tibial condyles:** Presence of medial osteophytes result in tenting and relative shortening of the medial collateral ligament (MCL).

In most varus knees there is medial femoral osteophyte that tents the medial collateral ligament and needs to be excised. The medial edge of resected medial femoral condyle is traced posteriorly and the osteophyte medial to it is resected with a straight narrow osteotome without injuring the MCL attachment to medial epicondyle. Osteophyctomy relieves the tenting effect and helps reversal of the varus deformity. (Fig. 5).

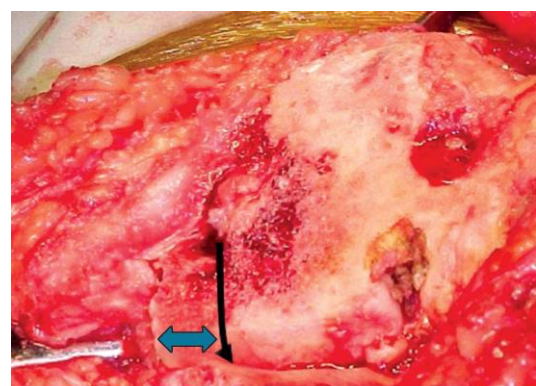


Fig 5: Resection of medial femoral osteophytes

- **Size the femur and posterior capsular release:** At this stage of surgery, it is useful to know the femoral size, which essentially depends on the anteroposterior dimensions of distal femur. Most modular systems allow size mismatch between femoral and tibial components. By knowing the femoral size, one can determine the smallest tibial size that will be compatible. At this stage, the joint is distracted in flexion to judge the extent of tightness on the medial side. If there appears to be significant tightness medially, one can increase the external rotation of the femoral component from 3–5° based on posterior condylar line. At this point, it is useful to resect only the posterior condyles of femur without the anterior or the chamfer cuts and the jig is removed. If there is any preoperative flexion deformity, the posterior capsule is released from the back of the femur. The curved osteotome is used to protect the important structures behind the capsule posteriorly.
- **Downsizing the tibia:** Tibia is then sized and compatible smallest size that will cover the lateral tibial plateau and be aligned to the junction of medial and middle one-third of the tibial tubercle is selected. This normally leaves overhanging bone medially and posteromedially. This overhang is resected flush with the medial edge of the tibial component. This technique is called reduction osteotomy (Fig. 6). The posteromedial surface of the upper tibia is thus sculpted so that indirect release occurs on the medial ligament by relieving the tenting over the flare of the posteromedial tibia. A reduction of 2 mm, usually results in correction of varus of 1°^[2]

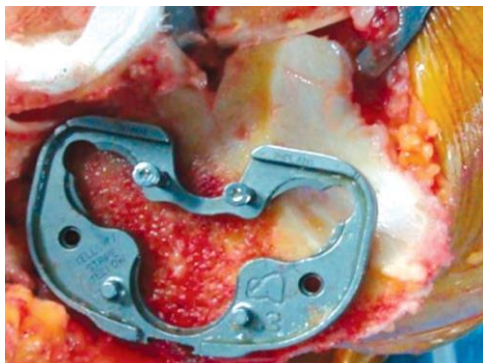


Fig 6: Downsizing the tibia

If deformity still persists, any of the following may be carried out:

- **Subperiosteal elevation of tibial attachment of superficial MCL:** Subperiosteal elevation of the tibial attachment of the superficial MCL will help further correction of the varus deformity. The pes insertion is identified. Using a periosteal elevator, careful partial elevation of the superficial MCL is performed posterior to the pes insertion. However, this carries the risk of mediolateral instability (if there is over-release or inadvertent total detachment of the superficial MCL) and results in the flexion gap exceeding the extension gap, both of which increase the potential need for a constrained prosthesis^[3]. On the other hand, leaving the knee with mediolateral imbalance due to inadequate medial release may lead to long-term instability, polyethylene wear, and potential loosening of tibial component from persistent adductor thrust^[4].
- **Release of pes anserinus insertion:** Partial release of the pes insertion by dividing it at right angles to the direction of fibers, starting proximally and going distally across the insertion helps correct the varus deformity. A spacer block may be used to check the adequacy of release. If the medial and lateral tension is still unequal, further division of the pes insertion is carried out by incising it further distally. In cases with severe tightness, complete division of the pes insertion may be required.
- **Medial epicondylar osteotomy:** Engh and Ammeen^[5] described the use of a wafer-thin medial epicondylar osteotomy (MEO) in conventional TKA to correct soft tissue contractures in varus knees during TKA. The MCL with a sliver of the medial epicondyle that includes the adductor magnus tendon insertion is detached using an osteotome. After correction of deformity, it is allowed to find its own position and no internal fixation is performed. The osteotomy may heal with osseous or fibrous union. In Engh and Ammeen's series, 46% of knees healed with fibrous union and 21% knees had a mediolateral laxity greater than 6°. This may be due to the fact that they did not fix the epicondylar fragment resulting in a high incidence of fibrous union and mediolateral laxity. However, they did not find focal tenderness, restricted motion, or other symptoms associated with fibrous union^[5].
- **Management of Associated Bone defects:** Severe varus deformity is usually associated with medial tibial condylar bone defects. Depending upon its dimensions, mostly prefers the following to manage them:
 - Less than 5 mm deep: When the defect is less than 5 mm deep, 2 mm holes are drilled into the sclerotic floor of the defect and it is filled up with bone cement.
 - More than 5 mm deep: After clearing all the sclerotic bone, a step cut defect is created with a gentle slope laterally. Bone graft from the resected intercondylar bone is fashioned to fill the defect and fixed with 2 mm Kirschner wires or cancellous screws. The wires or screws are passed parallel to the cut tibial surface.
- **Balancing the flexion gap:** In a nondeformed knee, not much soft tissue releases are necessary. Most systems use extension gap first technique and the techniques described above are used to get extension gap balancing. Flexion gap is determined next and is largely influenced by the degree of external rotation of the femoral component. Posterior condyles are commonly taken as reference points but need careful attention to the ensuing flexion gap. Transepicondylar axis (TEA) is considered a better landmark to judge femoral component rotation and normally TEA is on average at about 3° to the posterior condylar line in a normal knee (range 2–11°). In a varus knee, there may be some wear of the posterior condyle medially. In such a knee, one can still take posterior condyles as reference, as the femoral component will be in slightly more external rotation. This in fact improves the patellar tracking^[10]

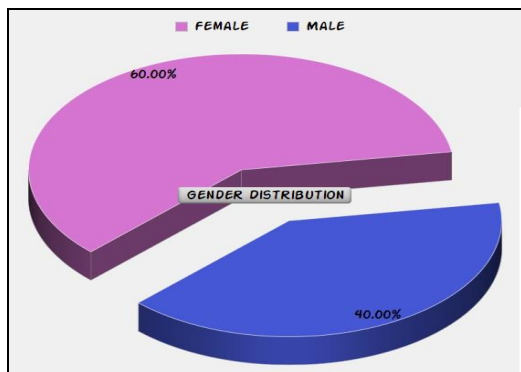
Results

Gender Distribution

There was a female predominance in the ratio of 3: 2 in our study, accounting for 60% of the patients. (Table 2 and Pie Chart 1).

Table 2: Gender Distribution.

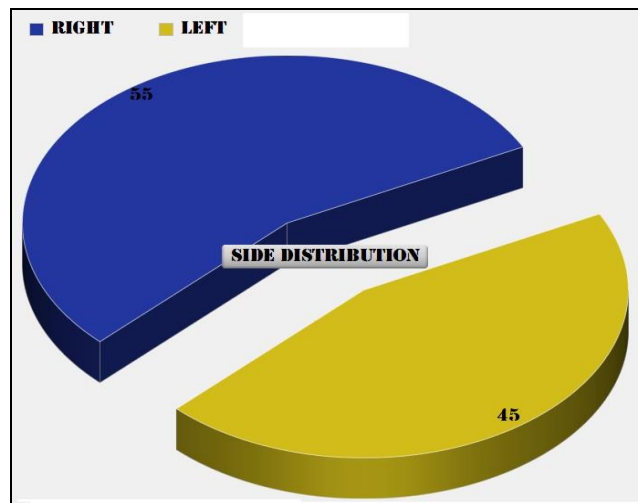
Gender	Frequency	Percent %
Female	12	60
Male	8	40
Total	20	100

**Pie Chart 1:** Gender Distribution**Side distribution**

There was a predominance of right side in our study, accounting for 55 % of the patients. (Table 3 and Pie Chart 2)

Table 3: Side Distribution

Side	Frequency	Percent %
Right	11	55
Left	9	45
Total	20	100

**Pie Chart 1:** Side Distribution**Immediate radiological evaluation of mean tibio-femoral angle after total knee arthroplasty.**

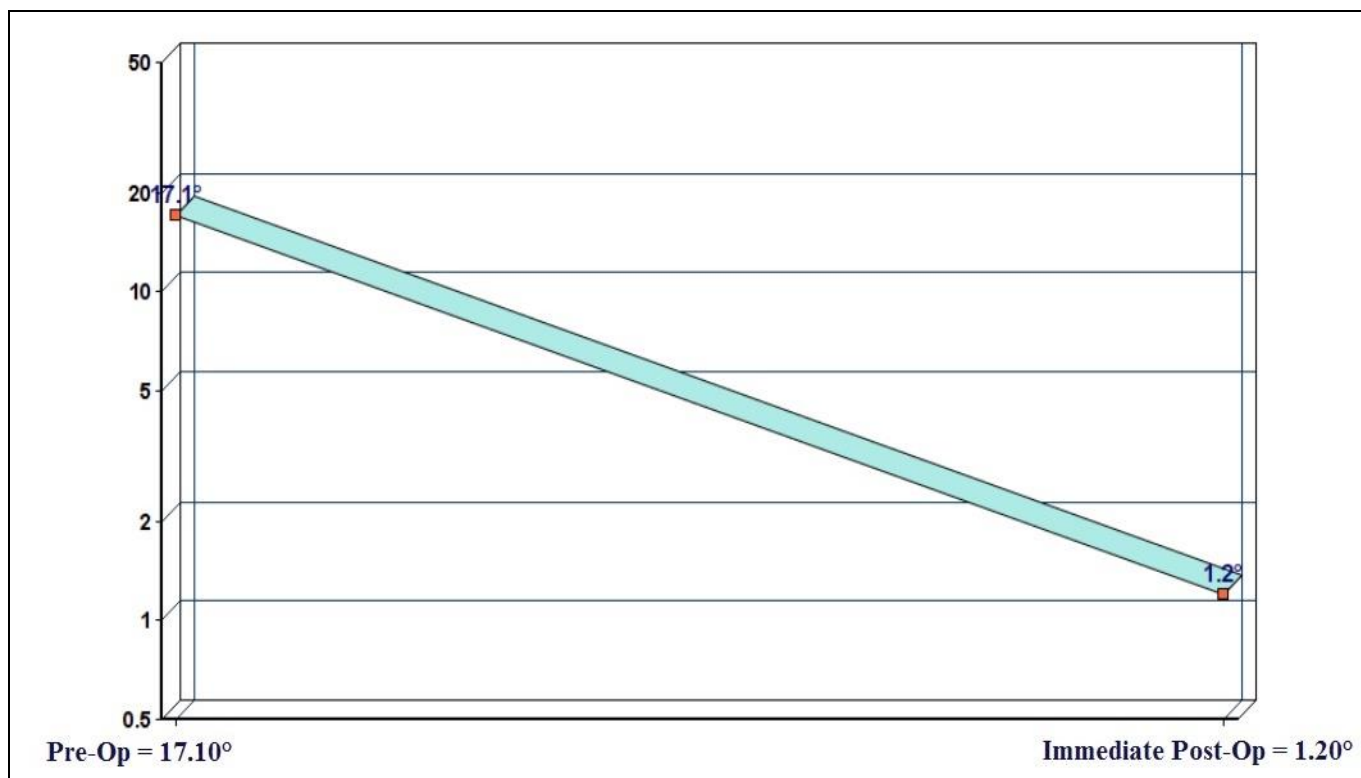
The mean tibio-femoral angle of all the patients was evaluated through Xray/Scanogram immediately post TKA. Table 4.

Table 4: Immediate Radiological Evaluation post TKA.

Radiological Evaluation	Mean Tibio-Femoral Angle (Mean Varus Deformity)
Immediate Post-Op	1.20°

**Gross varus deformity preoperatively.****Postoperatively with full correction of varus deformity.****Image 2:** Pre and Post TKA (13)**Comparison of radiological analysis of mean tibio-femoral angle (Mean varus deformity) before and after TKA.****Table 5:** Radiological Evaluation Pre and Immediate Post Operatively.

Pre-Op	17.10°
Immediate Post-op	1.20°



Graph 1: Radiological evaluation of man tibio- femoral angle (Mean varus)

Conclusion

Total knee arthroplasty (TKA) is one of the most successful surgeries that has alleviated the suffering of millions of knee arthritis sufferers all over the world, with over 90% survival rate at 10–15 years. (6) OA commonly results in a varus deformity since the weight-bearing axis of the lower limb passes medial to the center of the knee. Deformity in osteoarthritis at the level of the knee joint is a result of progressive cartilage wear, which in advanced cases may be accompanied by bone loss. This is commonly associated with contracture of the soft tissues on the medial side of the knee in varus deformities. Historical literature showed that restoration of lower limb alignment after TKA within $\pm 3^\circ$ of neutral ensures equal load distribution on the medial and lateral compartments which is essential for implant longevity [10]. From literature data, alignment in frontal plane must be into 2° or 3° range around a neutral alignment; this thought is demonstrated by Ritter *et al* who observed that prostheses implanted in varus position had a lower survival rate than prostheses implanted in a neutral or valgus position [17]. Jeffery *et al* observed that when mechanical axis was in 3° valgus-varus range, the loosening rate was 3%, whereas it's 24% when the alignment was out of this range [18]. Ligament balancing has been shown to be important in producing better limb alignment [22]. A series of normally aligned knees that went on to develop early medial insert wear progressing to varus malalignment pointed toward inadequate medial compartment ligament balancing as a possible cause [25]. Ligament balancing is a recognized key determinant of postoperative stability [26], and has been described as a possible preventable cause of the 27% of early knee revisions owing to instability [29]. The radiological analysis in our study shows that the excellent outcomes can be achieved for correction of varus deformity in a case of primary osteoarthritis during TKA when adequate biomechanical principles are executed.

In the years to come current designs of TKA prosthesis would

change, surgical techniques might get refined. However, what will never change are the basic principles of TKA. Thus, understanding principles rather than procedures is of paramount importance.

Disclosure

The author reports no conflicts of interest in this work.

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