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Analysis of Components Alignment in Total Knee Replacement Using Traditional Jigs And Its Relationship to The Functional Outcome

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Abstract :
Background:*Osteoarthritis is the most prevalent chronic joint disease affecting ambulation of a person. The incidence of osteoarthritis is rising because of the ageing population and the epidemic of obesity. Pain and loss of function are the main clinical features that lead to treatment.*
Aim and objectives:*To assess the components alignment in total knee replacement done using traditional jigs which include Varus, valgus and rotational alignment of tibial and femoral components*
Posterior tibial slope and posterior condylar offset preoperatively and post operatively. To assess the relationship between components alignment and the functional outcome.
Materials and methods:*A prospective study was done between the period of September 2013 – May 2015. 15 patients who underwent total knee arthroplasty were assessed clinically, functionally and radiologically.The follow up period was at 3 months, 6 months.*
Results:
- *Intramedullary jig for femur gave satisfactory coronal plane alignment of the femoral component.*
- *For rotational alignment of the femur in addition to the posterior condylar line, transepicondylar axis and whiteside line must also be compared for accurate rotational alignment.*
- *Extramedullary alignment jig for tibia provided satisfactory coronal plane alignment of the tibial component.*

Conclusion:
It's ideal to compare the position of the components with the anatomical landmark intraoperatively in addition to the jigs. When all the landmarks are used in total knee replacement using traditional jigs we can achieve proper component alignment.
Keywords :*TKR, Jigs*

I. Introduction

Osteoarthritis is the most prevalent chronic joint disease affecting ambulation of a person. The incidence of osteoarthritis is rising because of the ageing population and the epidemic of obesity[1,2,3]. Pain and loss of function are the main clinical features that lead to treatment.Total knee arthroplasty is now a reliable treatment for severe arthritis. Long term survivorship of total knee replacement depends on the proper alignment of the components. If there is malalignment in the components like when the tibial component is placed more in internal rotation then the length the patellar tendon increases, which causes maltracking of patella and rupture of extensor mechanism. Thus malalignment of components leads to various complications and affects the outcome of Total knee replacement. It is very important to assess the position of the components intraoperatively to avoid these complications

II. Materials Andmethods

This is a prospective study of fifteen patients to assess the components alignment and the functional outcome of total knee arthroplasty.

3.1 Kinematics of The Knee Joint

The knee motion during normal gait is not simple comprising of just flexion and extension, it is more complex, it includes flexion, extension, rotation, adduction and abduction. (Fig. 1)The articular geometry of the knee and the presence of various ligaments plays an important role in this complex motion of knee joint. Because of the complex motion of knee joint, designing an ideal implant for the knee joint and increasing the longevity of the implant is quite challenging.

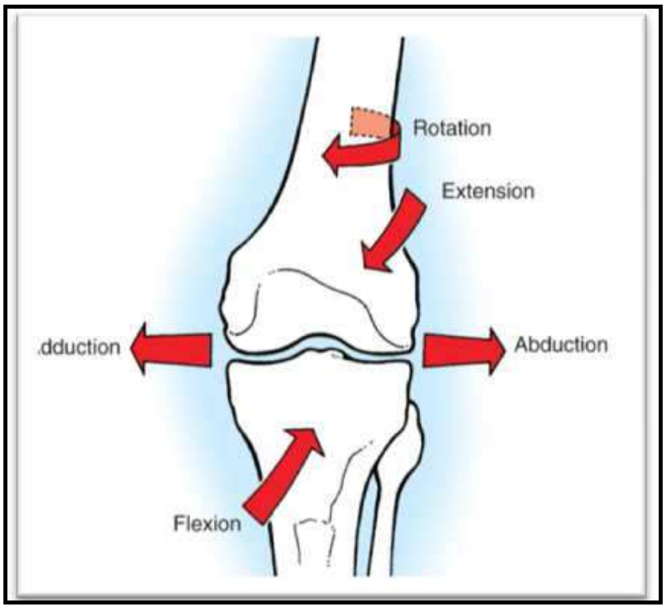


Fig.1 Kinematics of knee joint

Kettlekamp[5], analysed kinematics of knee joint and he concluded that "normal gait requires 67° of knee flexion during the normal swing phase, 83° of knee flexion during stair climbing, 90° of knee flexion for descending stairs and 93° of knee flexion to get up from a chair".

3.2 Tibio-Femoral Joint Articulating Surface Motion

The planar motion of the two adjacent body segments can be described by the concept of the instant center of motion. As one body segment rotates about the other, at any given instant, there is a point that does not move. This point has the zero velocity and acts as a center of rotation. This technique yields a description of motion at one point only and is not applicable if motion of 15 degree or greater exists in other planes. When the instantaneous center of rotation is at the contact point between femur and tibia, the instantaneous velocity is zero and the tibia is rolling around the femoral surface. An understanding of the motion between the articulating surfaces of knee joint is important for understanding causes of wear, instability and loosening of implants of the total knee arthroplasty.(Fig.2)

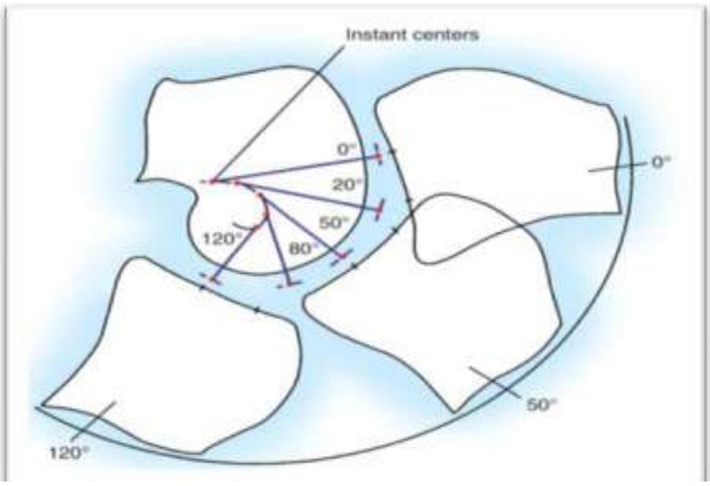


Fig.2 Tibiofemoral joint motion

They found the pathway to be semicircular and located in the femoral condyle. The centers fall within a circle with a diameter of 2.3 cm. Knee articulating motion is a combination of gliding and rolling between the femoral and tibial surfaces. The ratio of rolling to gliding is not constant throughout the range of flexion and is controlled by both the anatomy of the joint surfaces and constraints imposed by both cruciate ligaments. Muller considered that rolling to gliding ratio to be controlled by the basic model of a crossed four-bar linkage. In this mode, the tibial and femoral insertions of both cruciate ligaments are fixed to their respective surfaces and can be represented by two crossed bars. The cruciate bars are linked together at their attachments to the tibia and femur, and this link constitutes the two additional bars of the four-bar linkage. The tibiofemoral contact point moves posteriorly when the knee is flexed. The weight bearing surface of knee moves backwards on tibia and it is smaller during the flexion of the knee joint. According to Muller "In a normal knee during the full extension , centre of pressure is 25 mm from the anterior border of the knee joint and it moves posteriorly during the knee flexion to 38.5 mm from the anterior border of the knee joint".

3.3 Patellofemoral Motion

The main advantage of the patellofemoral joint is increasing the extensor leaver arm and thereby increasing the strength of the quadriceps contraction. The quadriceps tendon is attached to superior end of patella and patellar tendon is arises from inferior end of patella and displaces force vector away from knee joint. According to Muller "the extensor lever arm was maximum at 20 degree of knee flexion and the quadriceps force needed for the knee extension increases in the last 20 degree of knee extension". As the patella transmits the contractile force from the quadriceps to patellar tendon, it experiences an opposite force from the trochlea. This is called as joint reaction force. It depends on amount of flexion of knee and amount of force transmitted to patellar tendon. It increases with increase in degree of flexion of the knee. Biomechanical studies showed that "joint reaction force is around 2 to 5 times the body weight during the normal activities and increased to about 7 to 8 times the body weight during squatting". During the knee flexion patella glides through the trochlea, always in the clockwise motion.

3.4 Joint Surface

The constraints provided by the femoral and tibial joint surfaces are not adequate for functional stability. The distal femur is convex, whereas the proximal tibia is partially flat, slightly concave medially and slightly convex laterally. However, the tibial intercondylar eminence and the articular geometry provide some potential for stability. Heish and Walker found that geometric conformity of the condyles was the most important criteria for decreasing laxity under load bearing. They stated that in order to perform anterior or posterior, rotatory and medial or lateral movements, the femur must ride upward on the tibial curvature. Medial/lateral motion produces this effect to an even greater degree because of the tibial spines. This is called the "uphill principle". These authors concluded that under low loading conditions, the soft structures (ligaments, capsule and meniscus) provided joint stability and that as loading increases; the condylar surface conformity becomes the most important factor.

This study was done to analyse the clinical, functional outcome using knee society score and alignment of components using radiography and CT scan in total knee arthroplasty. A prospective study was done between the period of September 2013 – May 2015. 15 patients who underwent total knee arthroplasty were assessed clinically, functionally and radiologically. The follow up period was at 3 months, 6 months. The data was entered in Microsoft Excel 2010 and paired' T ' test and Chi-Square test were used to assess the statistical significance.

3.5 Inclusion Criteria :

1) All patients with arthritis knee undergoing primary total knee replacement.

3.6 Exclusion Criteria:

1) Paralytic conditions which affects early mobilisation
2) Post traumatic knee
3) Psychiatric illness
4) Ipsilateral hip and ankle pathology
5) Infection

3.7 Preopertive Evaluation:

Allpatients involved in the study were assessed clinically and radiologically

3.7.1 Clinical Assessment

Detailed history of all patients was taken. All patients were assessed clinically and functionally using the Knee Society Score. Preoperative medical evaluation of all patients was done to prevent the potential complications that were life-threatening or limb-threatening. All the cases were investigated and comorbid medical conditions brought under control before surgery pre op haemoglobin kept at minimum of 12 gms% and assessed. Any limb length discrepancies were noted. Presence of any hip and foot deformities was assessed. The extensor mechanism was assessed for any quadriceps contractures. The knee deformities were examined for any fixed varus or valgus deformities or presence of any fixed flexion contracture.

3.7.2 Radiographic Assessment:

Standard guidelines were utilized to get knee radiographs – standing anteroposterior view and a lateral view, presence of osteophytes, any bone defects in the tibia and femur and the quality of bone was assessed.Kellegren and Lawrence radiological grading was used to evaluate the severity of the arthritis and graded from I to IV as follows:

Table 1: Grading of osteoarthritis

Grade		Definition
I	Doubtful	small osteophyte, significance doubtful
II	Mild	Osteophyte Present, Joint Space maintained
III	Moderate	Moderate decrease in joint space
IV	Severe	Joint space greatly decreased, Sclerosis of Subchondral bone present

In the x rays following measurements were taken

1) Posterior condylar offset
2) Posterior tibial slope

Pre operative CTscanogram of both lower limbs from hip to ankle joint and following measurements were taken

1) Angle between anatomical and mechanical axis of femur
2) Varus / valgus deformity of knee joint.

3.8 Measurement

3.8.1 Anatomical and mechanical axis of femur.

CT scanogram from the hip to the ankle joint was taken. The line from the center of the femoral to the center of the knee is called as mechanical axis of femur. The line drawn from the center of the proximal femur to the center of the knee is called as anatomical axis of femur. The angle between this two lines is usually 6° to 7°. The line drawn from the center of the femoral head to the center of the ankle joint usually passes through the center of the knee joint. Any deviation from the center of the knee joint medially or laterally represents varus or valgus deformity of the knee joint. (fig 3)

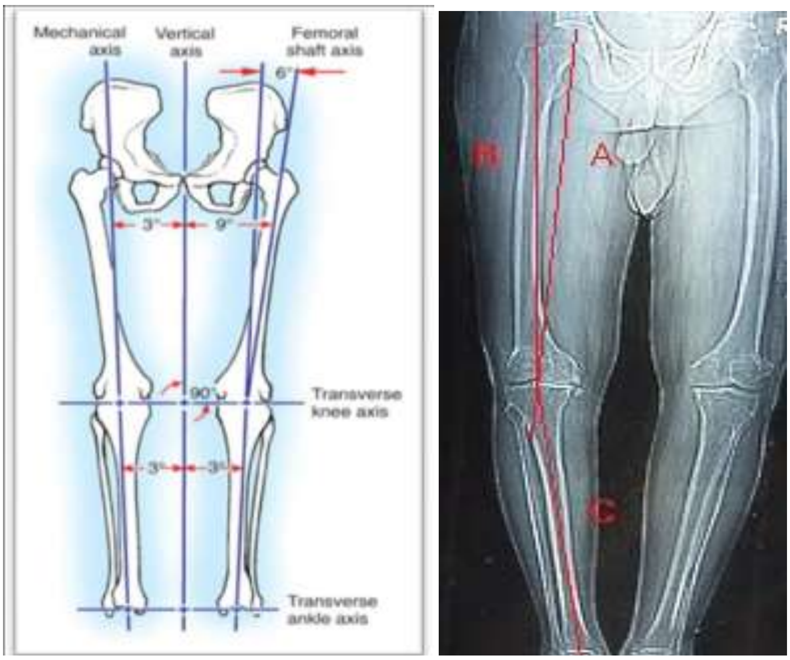


Fig 3: A is mechanical axis of femur, B is anatomical axis of femur, C is Tibial axis

3.8.2 Femoral component alignment

3.8.2.1 Axial alignment of femoral component

The normal axial alignment of the femoral component is 7 ± 3° valgus to the long axis of femur.(fig 4)

Fig 4 : The angle between the two lines indicate the valgus alignment of femur**.**

3.8.2.2 Rotational alignment of femoral component

CT scan was used to determine the femoral component rotation. It was calculated by angle between the line from medial sulcus of medial epicondyle to lateral epicondylar prominence and the line along the posterior condylar axis. Normal angle is 3.5 ± 1.2° internal rotation.(fig 5)

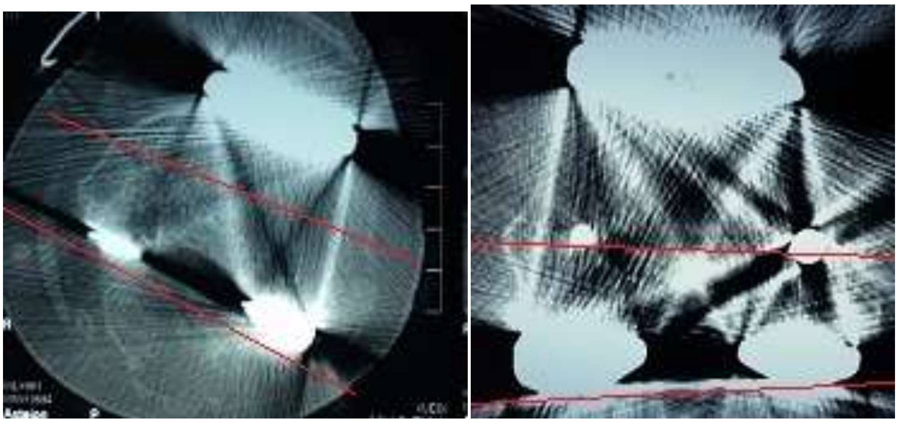


Fig 5 : The angle between the two lines indicate the rotational alignment of femur.

3.8.3 Tibial component alignment

3.8.3.1 Axial alignment of tibial component

The normal tibial component alignment is 90 ± 3° to the long axis of tibia.(fig.28)

Fig 6: The angle between the two lines indicate the alignment of tibial components

3.8.3.2 Rotational alignment of tibial component

CT scan was used to determine the rotational alignment of the tibial component. Central point of tibial plateau was located and a line along the posterior aspect of the tibial tray was drawn. A line perpendicular to this through the center was drawn. Then it was superimposed at the level of tibial tubercle and a line drawn from the tibial tubercle to the center. The angle between this two lines indicates the rotational alignment of tibialcomponent(fig.7). It is usually 18±2° of internal rotation.

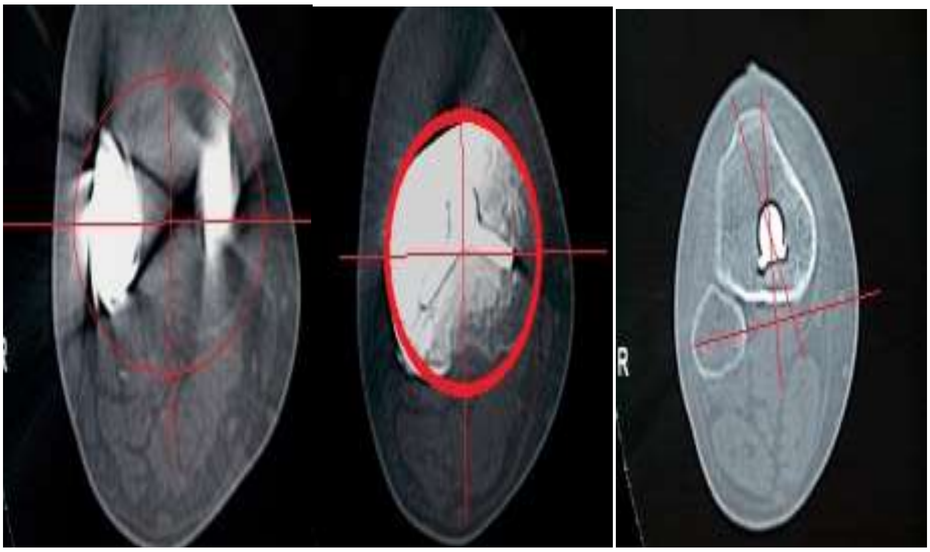


Fig.7: Alignment of tibial component

3.8.4 Posterior condylar offset

Distance between the line drawn along the posterior aspect of femur to the posterior femoral condyle in the lateral radiograph (fig 8).

Fig 8: Posterior condylar offset

3.8.5 Posterior tibial slope

In the lateral radiograph, the angle between the tibial slope and the perpendicular to the long axis of the tibia is the posterior tibial slope

(fig 9). The normal posterior tibial slope is 7° to 10°.

Fig 9: The angle between the two lines indicate the posterior tibial slope.

3.8.6 Knee Flexion

Flexion is calculated by taking lateral radiograph with knee in full flexion. Angle between the line along the long axis of femur and tibia indicates the flexion of the knee(fig 10).

Fig 10: Knee Flexion

3.9 Implant used :

For all our cases we used smith and nephew genesis II implant with deep dish.

3.9 Surgical Technique

Spinal anaesthesia was given for all the patients. Steps we followed during surgery includes Operative leg was painted and draped, stockinet applied, tourniquet applied. Then knee was flexed to 90° and anterior midline incision 5cm above superior pole of patella to tibial tubercle was made. Then through medial parapatellar approach knee joint was opened and patella was everted and lateral patella femoral ligament released. Then ACL was cut and all the surrounding osteophytes, lateral and medial meniscus was removed. Then lateral plateau was exposed with careful retraction of everted patella to avoid tension to the patellar tendon. Then the external tibial alignment jig was placed centred over the medial one third and lateral two third of the tibial tuberosity to the second toe and tibial cut was made with neutral posterior slope. Then posterior condylar axis, whiteside line and transepicondylar line was made over the femoral condyle and femoral entry point was made superior and medial to the intercondylar notch. Then intramedullary jig for femur inserted and then distal femoral cut made with 6° of valgus. Then flexion and extension gap was checked. Then femoral component size was measured using posterior reference guide and then 4 in 1 block resection guide placed and then anterior, posterior cut and chamfer cut was made. Then the tibial trial base was placed and then flexion extension gap and varus valgus stability checked. Then entry hole for tibial stem made then using threated keel punch entry made in tibia. Then trial reduction done and flexion, extension gap, varus/ valgus stability and patellar tracking was checked. Then bone cement was prepared and spread over the cut surfaces of femur and tibia and the implant was inserted and then once the cement sets poly of appropriate size inserted. Then osteophytes in the patella and circumferential denervation of patella done. Through wound wash given, drain kept and wound closed in layers. Sterile dressing done.

Fig 11; Surgical technique

3.10 Post – Op Protocol

Postoperative physical therapy and rehabilitation greatly influence the outcome of TKA. Initially, a compressive dressing applied to relieve pain and to decrease postoperative haemorrhage. Passive knee extension was encouraged by placing the patient's foot on a pillow while in bed. The postoperative rehabilitation protocol includes lower extremity muscle strengthening, concentrating on the quadriceps; gait training, with weight bearing and instruction in performing basic activities of daily living.The patients were started on IV antibiotics and DVT prophylaxis in the form of subcutaneous low molecular weight heparin.1st post op day, patient was taught static quadriceps exercises. 2nd post op day, the dressing was debulked and wound inspected. Patient was made to walk full weight bearing within the limits of pain and advised to continue static quadriceps exercises. IV antibiotics were given for the first 72 hours post op and DVT prophylaxis was given for the first ten days post operatively. 12th post op day, sutures were removed and patient was advised to continue regular physiotherapy.

3.10.1 Follow Up

The patient was assessed clinically, functionally using knee society score and radiologically at an interval of 3 months and 6 months.

IV . Results

Intramedullary jig for femur gave satisfactory coronal plane alignment of the femoral component.For rotational alignment of the femur in addition to the posterior condylar line, transepicondylar axis and whiteside line must also be compared for accurate rotational alignment.Extramedullary alignment jig for tibia provided satisfactory coronal plane alignment of the tibial component

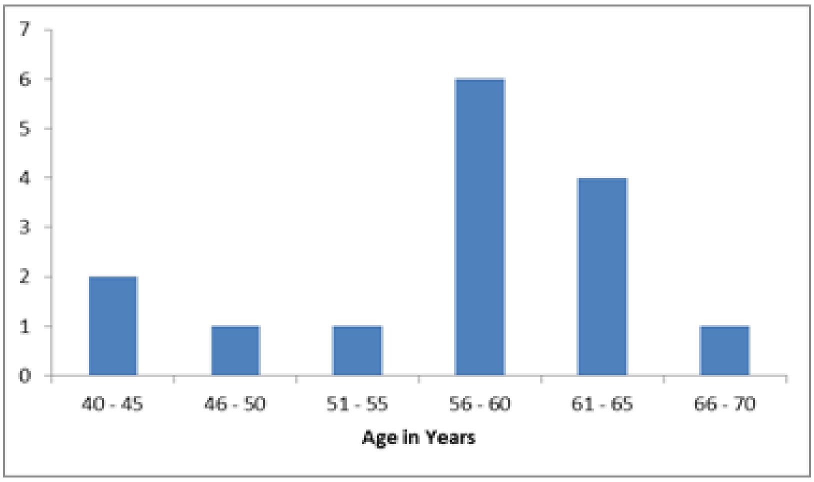


Fig 12: Age distribution

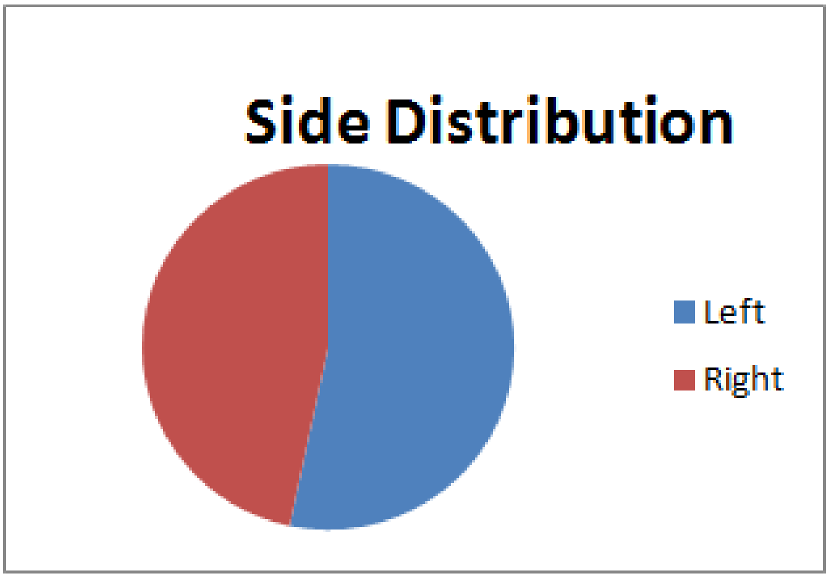


Fig: 13 Side distribution

Table 2: Gender distribution

Sex	Frequency	Percent
Male	9	60.0
Female	6	40.0
Total	15	100.0

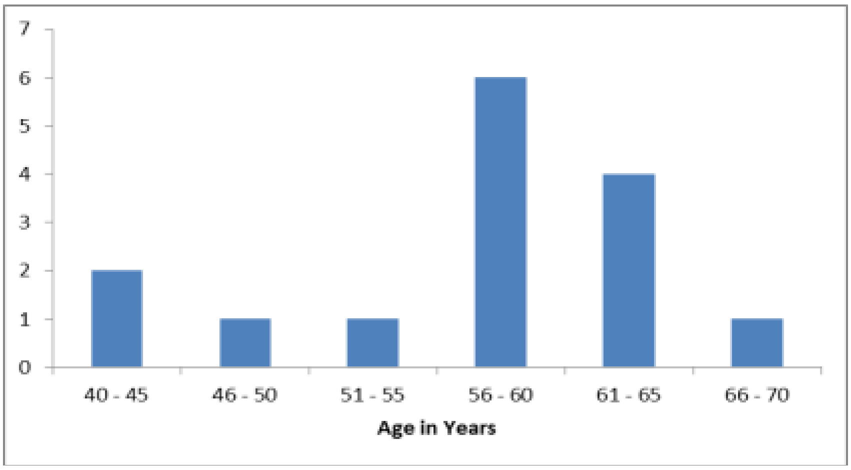


Fig 14: Age distribution

Most of the patients are in the age group of 56 to 60 which accounts for 40% in the study . Mean age is 57.2

Table 3: Gender distribution:

Sex	Frequency	Percent
Male	9	60.0
Female	6	40.0
Total	15	100.0

Table 4 : Side Distribution

Side	Frequency	Percent
Left	8	53.3
Right	7	46.7
Total	15	100.0

Table 5 : Comparison of Indications

Indication		Frequency	Percent
	OA	12	80.0
	RA	3	20.0
	Total	15	100.0

Table 6: Comparison between pre op and post op flexion

Knee flexion	Mean	P value
Pre op	82.67°	< 0.001
Post op	111.67°	

The mean preoperative knee flexion was 82.67° and the mean post operative knee flexion increased to 111.67° with significant p value of < 0.001.

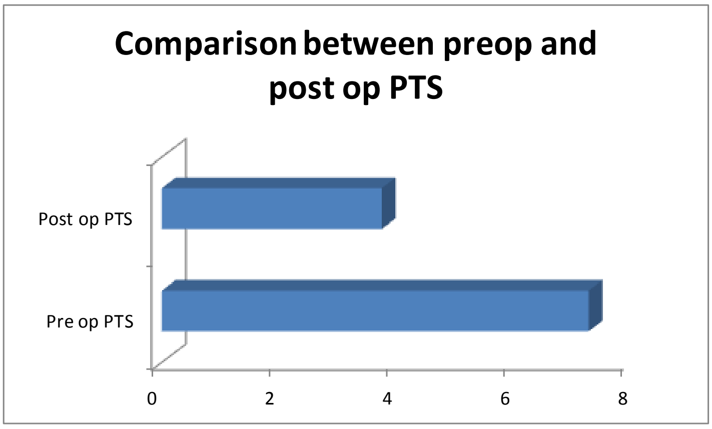


Fig 14: Comparison between pre op and post op posterior tibial slope

The mean post op posterior slope decreased from 7.24° to 3.73°.

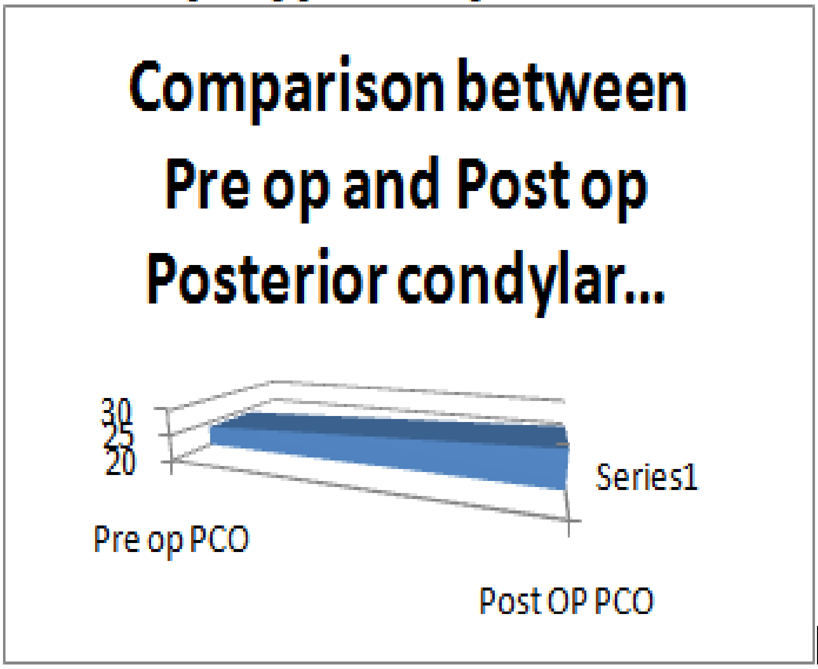


Fig 15: Comparison between pre op and post op posterior condylar offset

The mean preoperative posterior condylar offset is 24 mm which is increased to 27.20 mm with significant p value of < 0.001. There is positive pearson Correlation (0.093) between postoperative increase in posterior condylar offset and increase in postoperative knee flexion.

Table 7: Comparison between preop and post op Knee Clinical Score

Knee clinical score	**Mean**	**P value**
Pre op	28.13	< 0.001
Post op	94.60	

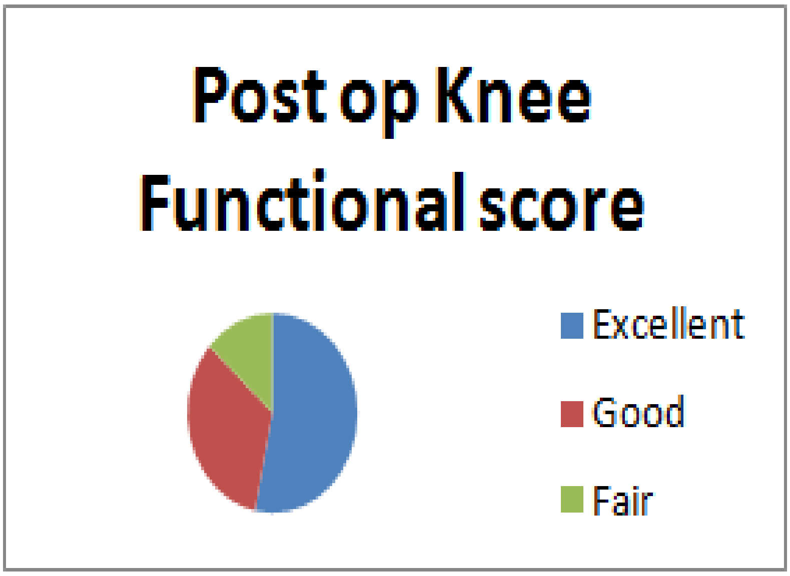


Fig 16: Knee functional score

There is significant improvement in knee clinical and knee functional score after surgery with p valve < 0.001.

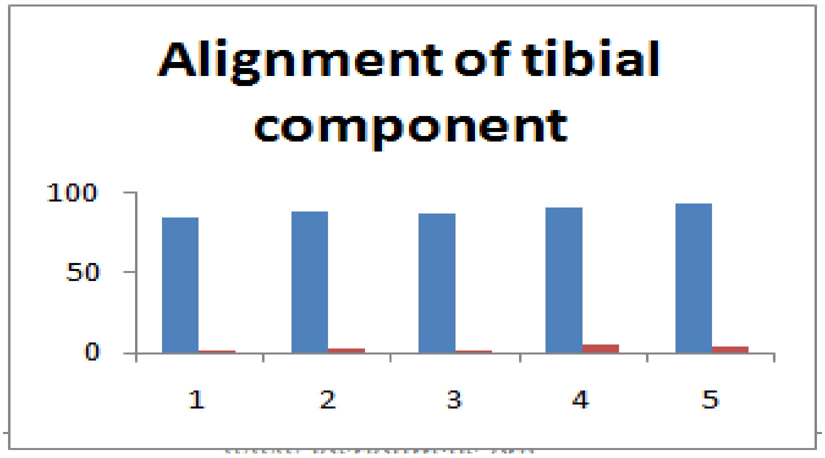
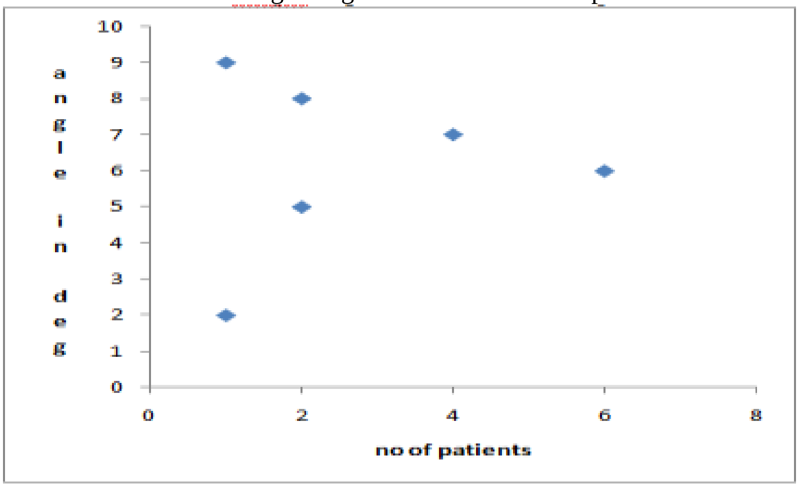


Fig 17: Alignment of tibial component

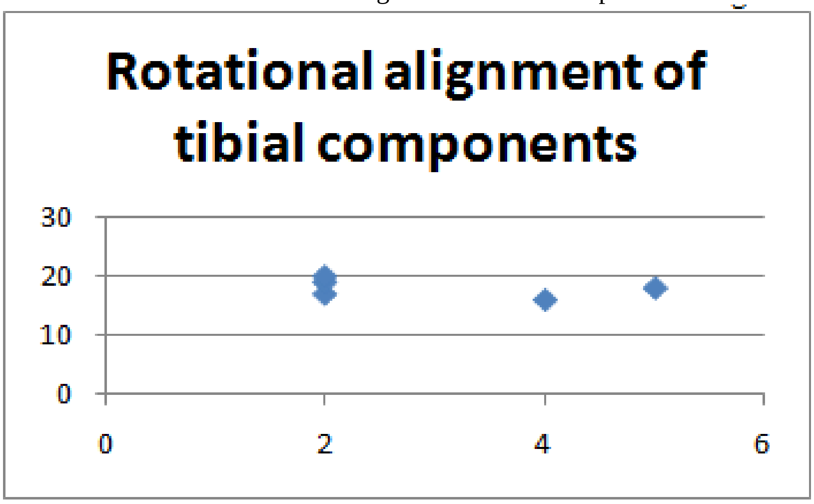
Tibial alignment ranges from 84° to 92° with maximum number of patients have 90°.

Table 8: Valgus alignment of femoral component



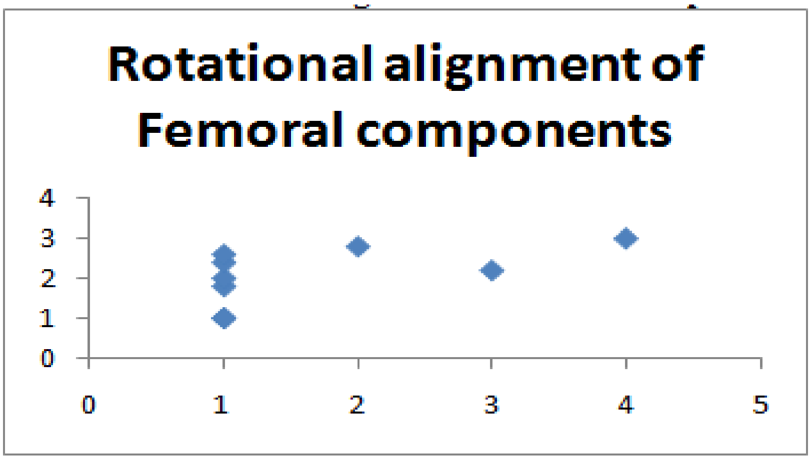
Femoral component alignment from 2° to 9° of valgus with maximum no of patients has 6° of valgus.

Table 9: Rotational alignment of tibial components



Tibial component rotational alignment from 16° to 20° with maximum patients has 18° of internal rotation.

Table 10: Rotational alignment of femoral components



Rotational alignment of femoral component ranges from 1.8° to 4° with maximum patients has 3° of internal rotation.

Table 11: Case I

Mr.Radhakrishnan 58/m Diagnosis: Osteoarthritis right knee	
Pre op knee flexion	70°
Post op knee flexion	115°
Pre of Knee clinical score	31
Pre op Knee functional score	92
Post op Knee clinical score	20
Post op Knee functional score	80
Preop Posterior condylar offset	26mm
Postop Posterior condylar offset	28mm
Pre op Posterior tibial slope	7°
Post op Posterior tibial slope	4°
Femoral component alignment Valgus Rotational	 8° 4°
Tibial component alignment Axial Rotational	 92° 16°

Pre Op **Post Op**

Fig 18: Case I

Table 12: Case II

Mrs Muniyammal 68/f Diagnosis: Osteoarthritis left knee	
Pre op knee flexion	75°
Post op knee flexion	105°
Pre of Knee clinical score	22
Pre op Knee functional score	98
Post op Knee clinical score	30
Post op Knee functional score	90
Preop Posterior condylar offset	22mm
Postop Posterior condylar offset	26mm
Pre op Posterior tibial slope	7°
Post op Posterior tibial slope	3°
Femoralcomponent alignment Valgus Rotational	 9° 2.4°
Tibial component alignment Axial Rotational	 92° 16°

Fig 19 : Case II

V . Discussion

Total knee arthroplasty is successful procedure and is associated with good functional improvement. There is good relief of joint pain, increased mobility, correction of deformity and an improvement in the quality of life of the patients following total knee arthroplasty. In this study fifteen patients were included who met the inclusion criteria and total knee replacement were done.In our study the mean tibial component alignment in coronal plane was 89.53° and sagittal plane was 3.73°, except one patient who had malalignment of tibial component in the coronal plane. We were able to achieve alignment of the tibial component within normal limit using external alignment jig for tibia. According to Jeffery et al[59] distal femoral resection was based on the intramedullary guide for femur and there was high chance for coronal malalignment of femoral component. But, in our study the coronal alignment was well maintained using intramedullary cutting jig for femur. The mean coronal alignment of femoral component in our study was 6.33°, except for one patient who had malalignment of femoral component in coronal plane.Müller et al reported in his study that there was 30 % malalignment of femoral components using intramedullary jigs for femur in posterior stabilised knee and associated with poor functional outcome. In our study there was one patient (6.66%) had malalignment of femoral component using intramedullary jigs for femur with suboptimal functional outcome.

According to the study by Young Wan Moon et al in total knee replacement done in 154 knees there was 34% malalignment of femoral and tibial components using jigs in posterior stabilized knees, in our study there was two patients (13.3%) who had malalignment.According to the study by Khardwakar and Kent et al, in 83 patients using intramedullary jigs for femur, taking 6° valgus cut for all patients was safe with postoperative mean valgus alignment of femoral component of 5.4° In our study also, 6° valgus cut was taken and the mean postoperative valgus angle was 6.33° with good functional outcome.According to Fujisawa et al "the postoperative mechanical axis should pass through the lateral one third of the tibial plateau with ideal postoperative lower limb alignment of 3°-6° of valgus from the mechanical axis or 8°-10° of anatomical valgus". In our study the mean valgus angle was 6.33°.

According to Bellman et al[60] "significant correlation between femoral condylar offset and maximal knee flection in 150 arthroplasties of the knee; every 1 mm increase in femoral condylar offset lead to a 6.1° increase in postoperative maximal flexion". In our study postoperative posterior condylar offset increased by a mean of 3.20 mm and the knee flexion increased by a mean of 29° with significant p value < 0.001.According to Bergar and Rubash the ideal placement of tibial component is 18±2° of internal rotation. In our study using the external alignment jigs for tibia, mean rotational alignment was 17.73°.According to Rubash, Richard and Berger et al "rotational alignment of the femoral component can be accurately estimated using the posterior condylar angle. The posterior condylar angle, referenced from the surgical epicondylar axis, provides a visual rotational alignment check during primary arthroplasty and may improve alignment of the femoral component at revision".

The rotational alignment of the femoral component which was saved in the registry report is 3.5±1.2°. In our study posterior condylar line was used as reference and the mean rotational alignment of the femoral component for femur was 3.14°. There was significant increase in flexion following total knee replacement. The mean preoperative flexion was 82.67° which increased to 111.67°.According to Lee M.Longstaffet al[61] "Good Alignment of components in total knee arthroplasty leads to faster rehabilitation and better functional outcome". In our study knee society score was used to assess the outcome of total knee arthroplasty and there was significant improvement of Knee Clinical Score and Knee Functional Score following Total Knee Arthroplasty.Two patients had fixed flexion deformity of 5° which was corrected with postoperative physiotherapy.In our follow up study the component position and alignment was well maintained. Long term follow up results are needed to strengthen the study.

VI . Conclusion

Restoration of neutral alignment is an important factor affecting the long-term results of total knee arthroplasty.

- Intramedullary jig for femur gave satisfactory coronal plane alignment of the femoral component.
- For rotational alignment of the femur in addition to the posterior condylar line, transepicondylar axis and whiteside line must also be compared.
- Extramedullary alignment jig for tibia provided satisfactory coronal plane alignment of the tibial component.
- It is ideal to compare the position of the components with the anatomical landmark intraoperatively in addition to the jigs.

When all the landmarks are used in total knee replacement using traditional jigs we can achieve proper component alignment. Large sample size and long term follow up are needed to further strengthen the study.

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