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Original Research Article

A prospective analytical study on the effect of posterior femoral condylar offset on range of knee flexion in patients undergoing cruciate retaining total knee arthroplasty

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ABSTRACT

Background: Osteoarthritis (OA) of knee joint is a common problem in our society causing pain, deformity, oedema, malalignment and limitation of activity. Total knee arthroplasty (TKA) is the surgery done for treatment of this problem. The range of movement obtained after TKA is an important factor influencing success of surgery. Posterior femoral condylar offset (PCO) is one of the parameters influencing range of movement after surgery. The dearth of studies in Indian population and contradicting results in already conducted studies has been observed in assessing the effect of PCO on range of knee flexion in patients undergoing TKA. Hence this study is done to explore this correlation.
Methods: A prospective analytical study on 36 patients (50 knees) who underwent cruciate retaining TKA at Department of Orthopaedics, Rajagiri Hospital, Aluva. PCO and posterior femoral condylar offset ratio (PCOR) were calculated radiologically before and after TKA. Range of flexion (ROF) and knee society scores (for functional outcome assessment) were recorded preoperatively and postoperatively (at 6 weeks and 3 months).
Results: The study found a strong positive correlation between PCO difference and ROF difference (r=0.735). Strong positive correlation was also found between PCOR difference and ROF difference (r=0.777). Both these correlations were statistically significant ($p<0.05$).
Conclusions: The study enlightened us about the point that PCO is an important factor in attaining a good ROF after cruciate retaining TKA.

Keywords: PCO, PCOR, ROF, Maximum flexion angle, TKA

INTRODUCTION

Osteoarthritis (OA) of the knee joint is a common debilitating problem prevalent in our society.[1] Increasing age, abnormal joint loading, trauma, autoimmune conditions, obesity, ligamentous injuries and meniscal tears are all compounding factors. Patients with knee OA present usually with pain, swelling, deformity, instability, decreased movement and limitation of activity. The radiographic findings observed include asymmetrical joint space narrowing or obliteration, subchondral sclerosis, subchondral cysts and osteophytes.[2]

Total knee arthroplasty (TKA) is a common surgery now done all over the world for treatment of advanced OA of the knee joint. Hence an artificial, painless, stable mobile joint is created. TKA can be PCL retaining type or PCL substituting type. TKA aims at restoring ROF, correcting deformities, stabilizing the joint and decreasing joint pain in standing and walking in order to carry out daily living activities. TKA not only restores functional capacity but also leads to a significant improvement in quality of life.

The range of movement (ROM) obtained after TKA is one of the most important measures influencing success of the

surgery. There are various factors influencing ROF like PCO, posterior tibial slope, preoperative ROM, implant design, soft tissue balancing.[3-8]

Numerous studies have also thrown light on other factors affecting ROF like age, sex, comorbidities, body mass index, surgical technique and post-operative rehabilitation regime.[9,10]

PCO is one such variable influencing ROF after TKA. It is the maximal thickness of the posterior condyle projected posteriorly to the tangent of the posterior cortex of the femoral shaft on true lateral knee radiographs.[6] PCOR is another method used in assessing PCO. It is the ratio of the PCO and the anterior-posterior dimension of distal femur.[11,12]

The restoration of the PCO has been shown to play a prominent role in maximizing the ROF after TKA. It has been found in certain studies that a reduction in the post-operative PCO correlated with a significant decrease in knee ROF after TKA.[6,13,14] While certain studies don't report any significant association between above mentioned variables.[10,15,16.]

It is of paramount importance to optimize knee ROF considering the fact that greater flexion is demanded by Indian patients. Daily activities (like toilet facilities) and cultural preferences demand deep flexion at the knee.[17-19] There are not many studies in Indian population exploring the effect of PCO on post-operative ROF. The dearth of knowledge pertaining to this relation has led to this study.

The objective of this study is to assess the correlation between PCO difference and change in knee ROF after cruciate retaining TKA after adjusting for known influential factors like posterior tibial slope, surgical techniques and implant design.

METHODS

Study design

The study design was a prospective analytical study.

Study area

The study conducted at IP (In patients) section of department of orthopaedics, Rajagiri hospital, Aluva.

Study population

Patients undergoing TKA aged between 50-80 years were selected.

Inclusion criteria

Patients with advanced OA admitted in department of orthopaedics undergoing TKA and TKA which is done by a single surgeon with single design implant (cruciate retaining) were included in the study.

Exclusion criteria

Patient who underwent previous open surgery in or around the knee in the previous 1 year, patient undergoing revision total knee replacement, stiff knee and patients who developed infection after TKR were excluded from study.

Study duration

The study conducted from 16 September 2019 to 01 June 2020.

Sample size

According to the study by Almedia et al titled "the posterior condylar offset ratio and femoral anatomy in anterior versus posterior referencing TKA", the mean and standard deviation of pre-operative PCO was 27.4±3.23 mm and mean and standard deviation of post-operative PCO was 30.1±3.81mm.[20] Applying in to this formula-

$$N = \frac{2\sigma^2(z_{(1-\alpha/2)}+z_{(1-\beta)})^2}{(\mu_T-\mu_S)^2}$$

$$\sigma = (\frac{s_1 + s_2}{2})^2$$

the required minimum sample size is 2 per each group.
μ_T: Mean of the test treatment= 27.4
μ_S: Mean of the standard treatment=30.1
$\mu_T - \mu_S$: Expected mean difference=2.7
σ: Polled standard deviation
s_1 : Standard deviation of test treatment=3.23
s_2 : Standard deviation of standard treatment= 3.81
α : Significance level 5%=1.96
1-β: Power=90%

The required minimum sample size is 36. But we had studied the characteristics of 50 knees, considering each operated knee even from same patient as a separate entity.

Study procedure

Study had commenced after getting clearance from scientific committee and ethical committee. All patients who fulfilled the inclusion criteria were taken up for TKA. If both knees of a patient were operated, each knee was taken as a separate entity. All measurements and examinations were done by a single observer. After surgery, patients were started with full weight bearing walking with walker. Range of motion exercises, quadriceps strengthening exercises and gait training were done after postoperative day 1 depending on the pain tolerated by the patient. Patients were advised not to squat or sit cross legged after surgery.

Preoperative and post-operative true lateral knee radiographs were assessed for all patients. The radiographs were taken using Siemens Multiphos 450 machine. PCO and anteroposterior width at level of femoral condyles (APW) was measured in both radiographs using radiant Dicom viewer. PCOR was also calculated using the PCO and APW.

ROF of knee joint was measured with the help of a single goniometer. ROF and knee society scores were recorded preoperatively (one day before surgery) and at post-operative visits of 6 weeks and 3 months after surgery. Knee society scores were used to assess the functional outcome of patients undergoing cruciate retaining TKA.

Methods of measurement of outcome of interest

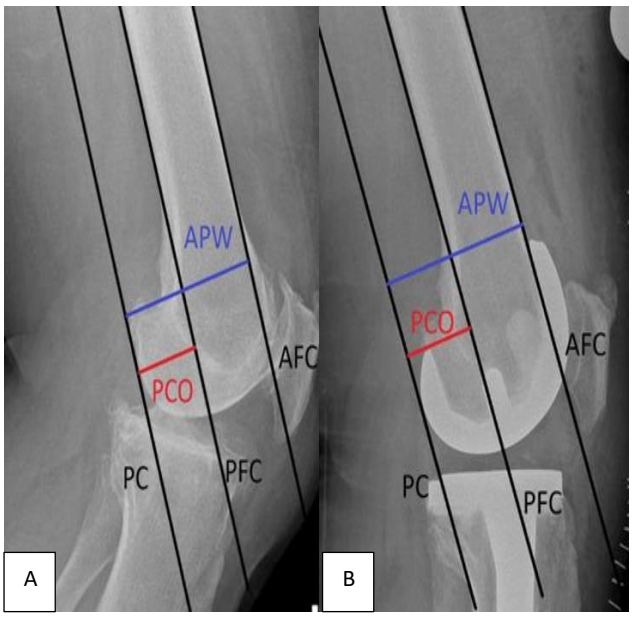

Figure 1 (A and B): Preoperative lateral knee radiograph with measurements and postoperative lateral knee radiograph with measurements.
PCO-Posterior femoral condylar offset distal femur, APW-Antero-posterior width at level of femoral condyles, PFC-Tangent along posterior femoral cortex, PC-Tangent along posterior most aspect of femoral condyles parallel to tangent along posterior femoral cortex, AFC-Tangent along anterior femoral cortex condyles parallel to tangent along posterior femoral cortex.

PCO (mm): It is the maximal thickness of the posterior condyle projected posteriorly to tangent of the posterior cortex of the femoral shaft on true lateral knee radiographs.

PCOR: Ratio of the PCO to the anterior-posterior width of distal femur (PCOR=PCO/APW).

ROF of knee: Measurement of active ROF of the knee joint in degrees. Maximum flexion angle (MFA) of knee is the maximum flexion attained by knee when assessing ROF. It is noted that when a patient has no flexion contracture, his ROF will be equal to the maximum flexion angle. However, in case of flexion contracture his ROF will be less than the maximal flexion angle. It is to be noted that MFA is a component of ROF and when assessing PCO correlation, maximum flexion attained by the knee is changed which in turn affects the ROF.

Knee society scores: Measured by clinical examination and making the patient answer a questionnaire. It has 2 components-knee society rating and a function rating.

Knee score: It has a total score out of maximum of 100. This includes assessment of various parameters like pain, total ROF, antero-posterior stability, mediolateral stability, alignment (varus & valgus), flexion contracture and extension lag. A knee score of 80-100 as excellent, 70-79 as fair, 60-69 as fair and score below 60 as poor.

Function score: It also has a total score out of maximum of 100.This includes analyzing factors like walking, stairs and walking aids used.

Surgical procedure

Initially the patient was given spinal anesthesia along with epidural analgesia. Later the patient was positioned in supine position with thigh support. Tourniquet was applied and the operative area was scrubbed, painted and draped in a sterile manner utilizing disposable drapes. Anterior midline longitudinal incision (15 cm incision) was put with knee in flexion. A medial sub vastus approach was used in all cases. Medial release was done and patellar fat pad partially removed. Patella was subluxated laterally and the knee flexed. Intramedullary rod passed after making an opening 1cm anterior and medial to trochlear notch and intramedullary jig was inserted. Distal femoral cuts were taken at 5-degree valgus with the anatomical axis of femur. Later Tibia was subluxated anteriorly. Remnants of both menisci and anterior cruciate ligament were removed. Proximal tibial cut was taken using extra medullary tibial jig with 5-degree posterior slope. Tibial size was measured and extension gap assessed. Femoral sizing was done with anterior referencing. The jig used for taking anterior, posterior and chamfer cuts was placed on distal femur in 3-degree external rotation. The rotational alignment was then reassessed and confirmed with reference to the Whiteside's line, posterior condylar axis and trans-epicondylar axis. Anterior, posterior and Chamfer cuts in distal femur were then taken. Posterior cruciate ligament was assessed and kept intact. Posterior joint osteophytes and Patellar osteophytes were removed. Trial femoral and tibial components with insert were placed and checked for patellar tracking, mechanical axis alignment and varus - valgus stability in flexion and extension. Femoral and Tibial sites were prepared. Thorough wash was given with pulse lavage. Cruciate retaining TKA implants were used in all cases. The polymethylmethacrylate bone cement (PMMA) was applied over the cut bone surfaces in a doughy state. A Tibial tray of appropriate size was applied using bone cement. A cruciate retaining polyethylene insert was applied onto the tibial tray. Later the femoral

component of appropriate size was implanted with the cement. Excess cement was later removed. Normal patella tracking was confirmed. Stability was reassessed in flexion and extension and confirmed. Tourniquet was released and hemostasis achieved. Wound was closed in layers and sterile compression dressings were given.

Statistical tool (software) used

SPSS version 25 software was used to analyze data. Initially relevant data was entered in Microsoft excel software and later SPSS 25 software utilized.

Statistical methodology

Quantitative variables were expressed as mean and standard deviation. Median and interquartile range was used for non-parametric quantitative data (e.g., score). Qualitative variables were expressed as frequency and percentages. Paired t test for quantitative parametric variables. Paired t test was done to compare paired means. Linear regression was done to generate an equation to predict the value dependent variable. Pearson correlation coefficient (r) was calculated for comparing 2 continuous variables. Friedman's ANOVA was done as non-parametric test of scores of patients pre-operatively and post-operatively. Post hoc analysis using Wilcoxon signed rank test and Bonferroni correction was done for assessing significance in post hoc analysis. P<0.05 will be considered to be statistically significant.

RESULTS

We enrolled 36 patients (50 knees) who were admitted in the Department of Orthopaedics at Rajagiri Hospital, Aluva. 14 patients underwent bilateral TKA, while 22 patients underwent unilateral TKA. The patients underwent cruciate retaining TKA for knee OA.

Age distribution

Maximum numbers of patients in our study were in the 66-70 age group, followed by the 61-65 age group.

Table 1: Distribution (age in years) of patients undergoing TKA.

Age group (years)	Number	Percentage (%)
51-55	1	2.8
56-60	2	5.6
61-65	9	25.0
66-70	11	30.6
71-75	8	22.2
76-80	5	13.9
Total	36	100.0
Mean±SD (Range)	68.83±5.99 (55-80)	

Sex distribution

Majority of the patients in the study were females. It is noted that out of the 10 male subjects 3 underwent bilateral TKA, while 11 of the 26 female subjects underwent bilateral knee replacement.

Table 2: Gender distribution in patients undergoing TKA.

Gender	Number	Percentage (%)
Male	10	27.8
Female	26	72.2
Total	36	100.0

Table 3: Difference in PCO in lateral knee radiographs following TKA in 50 knees.

PCO	Mean (mm)	SD	Min	Max	P value
Pre-op	27.30	2.06	23.13	31.83	0.250
Post-op	27.65	2.14	23.54	33.41	
Difference	0.35	2.15	-3.67	3.71	

The mean difference in PCO was 0.35 mm±2.15 mm. This was not found to be the statistically significant with the p>0.05.

Table 4: Difference in PCOR following TKA in 50 knees.

PCO ratio	Mean	SD	Min	Max	P value
Pre-op	0.47	0.02	0.43	0.51	1.000
Post-op	0.47	0.02	0.43	0.52	
Difference	0.00	0.02	-0.04	0.04	

The mean difference in PCOR was 0.00±0.02. This was not statistically significant (p>0.05).

The mean difference in ROF between preoperatively and 6 weeks was -4.28±6.41 degrees, while the mean difference in ROF between preoperatively and 3 months was 3.78±8.56 degrees. Both were found to be statistically significant (p<0.05).

The PCO difference shows a weak positive correlation (r=0.492) with knee ROF difference at 6 weeks. The PCO difference shows a strong positive correlation (r=0.735) with knee ROF difference at 3 months. Both correlations were statistically significant (p<0.05).

The PCOR difference shows a moderate positive correlation (r=0.567) with knee ROF difference at 6 weeks. The PCOR difference shows a strong positive correlation (r=0.777) with knee ROF difference at 3 months. Both correlations were statistically significant (p<0.05).

Table 5: Difference in knee ROF (degrees) at 6 weeks and 3 months postoperatively in 50 knees.

ROF	Mean	SD	Min	Max	Pre-op vs 6 weeks (p value)	Pre-op vs 3 months (p value)	6 weeks vs 3 months (p value)
Preoperative	106.88	7.64	83	120			
6 weeks	102.60	5.81	88	115			
3 months	110.66	8.11	90	120			
Difference baseline to 6 weeks	-4.28	6.41	-14	17	<0.001	0.003	<0.001
Difference baseline to 3 months	3.78	8.56	-10	27			

Table 6: Correlation between PCO difference and ROF difference at 6 weeks and 3 months post operatively.

Variables	Pearson's correlation coefficient (r)	P value
PCO difference vs ROF difference 6 weeks	0.492	<0.001
PCO difference vs ROF difference 3 months	0.735	<0.001

Table 7: Correlation between PCOR difference and ROF difference at 6 weeks and 3 months postoperatively.

Variables	Pearson's correlation coefficient (r)	P value
PCOR difference vs ROF difference 6 weeks	0.567	<0.001
PCOR difference vs ROF difference 3 months	0.777	<0.001

Table 8: Distribution of patients according to knee score (knee society score) preoperatively, 6 weeks post-surgery and 3 months post-surgery.

Knee score range	Pre-op number of knees	6 weeks post-op number of knees	3 months post-op number of knees
80-100 (excellent)	0	48	50
70-79 (good)	2	2	0
60-69 (fair)	18	0	0
<60 poor	30	0	0

Out of the total of 50 knees preoperatively 30 knees had poor score,18 knees had fair score and 2 knees had good score. 6 weeks after surgery 48 knees had excellent outcome and 2 knees had good outcome. Three months after surgery all 50 knees had an excellent outcome.

Median knee score at preoperative, 6 weeks post-surgery and 3 months post-surgery was found to be 55, 86 and 92 respectively. Median function score at preoperative, 6 weeks post-surgery and 3 months post-surgery was found to be 55, 70 and 80 respectively. Friedman's ANOVA was done to assess the difference in knee score as well as function score (Knee society scores) preoperatively and post operatively and it was significant with a $p<0.05$ ($p=0.001$). Post hoc analysis with Wilcoxon signed rank test, with Bonferroni correction (for alpha error) applied. It was observed that both knee score and function score showed significant improvement during the 2-time intervals, that is from preoperatively to 6 weeks post-op and from 6 weeks post-op to 3 months post-op with a $p<0.05$ ($p=0.001$).

Using linear regression, maximal knee flexion angle difference=0.948+3.027 (PCO difference). The study at 3 months after surgery revealed that for every 1 mm decrease in PCO there was a decrease of maximum flexion angle by 2.079 degrees. For a 10 degree decrease in maximum flexion angle there would be a decrease of 3.62 mm in PCO.

DISCUSSION

The mean pre-operative PCO found in our study was 27.30±2.06 mm and mean postoperative PCO was 27.65±2.14 mm. The mean pre-operative ROF was 106.88±7.64 degrees and mean ROF at 3 months after surgery was 110.66±8.11 degrees. The mean pre-operative MFA of knee was 108.64±5.78 degrees and mean MFA at 3 months after surgery was 110.66±8.11 degrees.

A study conducted by Kittanakere et al found mean pre-operative PCO to be 26.42±1.88 mm, mean post operative PCO to be 25.94±1.89 mm and the difference was not statistically significant ($p=0.097$).[21] In a study done by Arbori et al the mean preoperative PCO was 25.3 mm in the CR knees, while the mean postoperative PCO was 24.3 mm.[14] Bellemans et al in their study found a mean preoperative PCO of 25.8 mm (SD=2.9),mean post-operative PCO of 23.6 mm (SD=3.8), mean PCOR of 0.47±0.02 and the mean post-operative PCOR of 0.47±0.02.[6] A similar study done in Indian population by Kittanakere et al found the mean pre-operative PCOR to be 0.45±0.02,the mean post operative PCOR to be

0.45±0.02 mm.[21] A mean PCOR of 0.44 (SD=0.02) was found by Johal et al on assessing 100 knees.[11]

The PCO difference was noted to have a strong positive correlation (r=0.735) with knee ROF difference at 3 months after TKA. The PCOR difference was found to have a strong positive correlation (r=0.777) with knee ROF difference at 3 months after TKA. The PCO difference exhibited a strong positive correlation (r=0.813) with knee MFA difference at 3months after TKA. The PCOR difference was noted to have a strong positive correlation (r=0.801) with knee MFA difference at 3 months after TKA. The study at 3 months after surgery revealed that for every 1 mm decrease in PCO there was a decrease of maximum flexion angle by 2.079 degrees. Bellemans et al in their study found that for every 1mm decrease in PCO there was a 6.1 degree decrease in knee MFA in PCL retaining knee.[6] Hence leading to a decrease in ROF. The mean preoperative ROF was 105.0 degrees (SD=20.2) and the mean post-operative ROF was 105.9 degrees (SD=17.3). They also noted that a reduction in PCO correlated with a reduction in MFA (R2=0.58, p<0.001) and hence a reduction in the ROF. Malviya etal found following division of 101 patients in 3 groups found that the mean PCO difference was 2.3mm (SD 2.9) in first group (p=0.51),1.8 mm (SD 2.7) in second group (p=0.51) and 1.6 mm (SD 2.8) (p=0.60) in third group.[13] The PCOR difference were 0.07 (SD=0.09) in first group (p=0.45), 0.06 (SD=0.09) in second group (p=0.45) and 0.05 (SD=0.08) in third group (p=0.43). The mean preoperative ROF (in degrees) were 94 (SD=18) in first group (p=0.15), 100 (SD=18) in second group (p=0.15) and 104 (SD=16) in third group (p=0.046). The mean 12 months post-operative ROF (in degrees) were 106 degrees (SD=14) in first group (p=0.73), 107 degrees (SD=12) in second group (p=0.73) and 107 degrees (SD=10) in third group (p=0.89). When all the groups were assessed, the range of movement at 12 months showed a moderate positive correlation with PCO difference (r= 0.65, p<0.0001) and 12-month ROF also exhibited a moderate correlation with PCOR difference (r=0.64, p<0.0001). Gournay et al had postulated that a 3 mm decrease in PCO would lead to a 10 degree decrease in flexion.[22] Arbori et al on assessment found that there existed a significant difference in post-operative flexion between Group I (subjects with decrease of PCO) and group II (patients with no decrease in PCO) (p<0.05).[14] The mean knee MFA here were noted to be 120±18 degrees before TKA and 123±15 degrees after cruciate retaining TKA. Our study found that a decrease in PCO lead to a decrease in ROF as well as maximum knee flexion angle. When there is terminal flexion of knee beyond 90 degrees, the posterior aspect of condyles articulates with proximal tibia. This is the significance of PCO. During the surgery the posterior bone cuts of distal femur is taken using jig along with other bone cuts and later the implant is applied. Hence it is ideal to recreate the PCO after TKA. Hence the ROF attained when patient actively flexes knee might be limited by direct impingement of posterior aspect of tibial insert against posterior cortex of shaft of femur. Also factored in is the mechanical block caused by the impingement associated with a forward sliding of the femur during flexion which leads to a decrease of flexion after CR TKA when there is reduction of PCO.

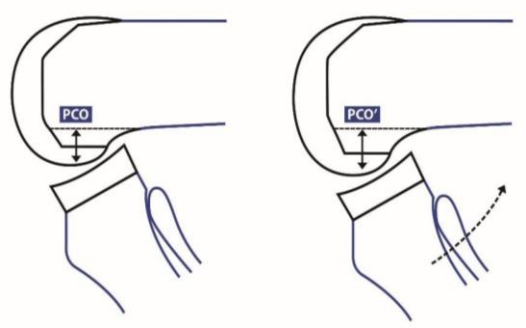

Figure 2: Reduced PCO leads to early impingement and reduction in flexion.

However, contrary to above findings, Ishii et al concluded that no correlation existed between change in PCO and difference in post-operative knee ROF at 1 year in patients who underwent cruciate retaining (CR) TKA.[15] The study calculated the mean postoperative differences in medial and lateral PCO to be 0.0±3.6 mm and 3.8±3.6 mm, respectively. The knee MFA was 117±17 degrees before TKA and 112±15 degrees after TKA. The change in MFA was found to be 5±15 degrees. In the above-mentioned study by Ishii et al assessment was done using preoperative CT images of femur and tibia of each patient. Biplanar computed radiography was also used to create a quantitative 3D technique to take measurements. The medial and lateral femoral condylar offsets were also measured separately. It was found that no correlation existed between post-surgery knee flexion angle and PCO change in medial condyle (r=0.049, p=0.654) and also no correlation existed between post-surgery knee flexion angle and PCO change in lateral condyle (r=-0.041, p=0.712). It is to be mentioned here that our study had measured the PCO and anteroposterior width in true lateral knee radiographs with overlap of both medial and lateral condyles. Hence, we were getting a single value for PCO and this in turn was used for calculating PCOR. Similarly, Harsha et al found no significant correlation between PCO and amount of post-operative flexion attained.[10] In a study done by Kittanakere et al no significant correlation was found between PCO difference and MFA (hence ROF) at 3 months and 6 months post-surgery (r=-0.158 and r=-0.030 respectively).[21] It was also noted that no significant correlation was found between PCOR difference and MFA (hence ROF) at 3 months and 6 months post-surgery (r=-0.073 and r=0.007 respectively). However, these studies were conducted in patients undergoing cruciate sacrificing TKA. The changes in PCO seem to be more important in cruciate retaining TKA prosthesis and less significant in posterior stabilized or PCL knee prosthesis. Hence it implies that PCO does have a significant bearing on the amount of flexion attained after cruciate retaining TKA. However, in PCL sacrificing knees the kinematics and roll

back is determined and under effect of the prosthesis design. The implant design decreases the risk of impingement. It is to be mentioned here that PS knees are not constrained by the native posterior cruciate ligament.

Knee society scores were calculated to assess functional outcome. Both the function and knee score showed significant improvement after TKA when compared to preoperative scores. This was noted in all patients. It supports the fact that TKA is very good in alleviating the disability caused by knee OA. It not only provides a huge relief in pain but also corrects various deformities.

Limitations

There are still few limitations for our study. We had assessed flexion at follow-up for 3 months after surgery. A longer follow- up study would have helped us paint a more wholesome picture of correlation between PCO and ROF. We had put our best effort in accurate radiographic measurement of pre- operative PCO. But still some error might still creep in because the thickness of cartilage on the posterior aspect of femoral condyles might not be accounted for during measurement of PCO before surgery. Some amount of rotation was still encountered during taking of the lateral knee radiograph. This might be a hindrance in assessing the correlation of PCO with knee ROF.

CONCLUSION

The study enlightened us about the fact that PCO has an important effect on postoperative knee ROF attained in cruciate retaining TKA. The attainment of a good ROF after TKA is a main prerequisite for Indian population for carrying various daily activities. Exploration of various factors affecting ROF in an evolving area of interest. This study brings to light the need for restoration of PCO for attaining maximum ROF after cruciate retaining TKA. A decrease in PCO after TKA would lead to a decrease in ROF. In view of the continuing battle for the treatment of the disability caused by knee OA, this study will definitely be a step forward.

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Ethical approval: The study was approved by the institutional ethics committee

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