International Journal of Research in Orthopaedics
Jishnu Krishnan K et al. Int J Res Orthop. 2026 Jul;12(4):1049-1054
https://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20262038

Influence of femoral posterior condylar offset on functional outcomes following posterior-stabilized fixed bearing total knee arthroplasty: a prospective observational study

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Received: 02 May 2026
Accepted: 11 June 2026

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ABSTRACT

Background: Total knee arthroplasty (TKA) provides effective pain relief and functional improvement in advanced osteoarthritis; however, suboptimal postoperative knee flexion persists in some patients. Femoral posterior condylar offset (PCO) is an important determinant of femoral rollback, flexion gap balance and quadriceps efficiency, particularly in posterior-stabilised (PS) TKA. Evidence regarding its influence on functional outcomes remains inconsistent, with limited data from the Indian population.
Methods: A prospective observational study was conducted in 21 patients aged 50–80 years with Kellgren–Lawrence grade 3 or 4 osteoarthritis undergoing posterior-stabilised, fixed-bearing primary TKA between April 2024 and September 2025. Preoperative and postoperative PCO and posterior condylar offset ratio (PCOR) were measured using true lateral radiographs. Functional outcomes were assessed using the Knee Society Score (KSS) at 6 weeks, 3 months and finally at 6 months. Statistical analysis evaluated the association between PCO changes and functional outcomes.
Results: The mean age was 66.81±5.56 years. KSS showed significant improvement over time ($p<0.001$). Most patients demonstrated minimal changes in PCO (0–2 mm). Patients with preserved or minimally increased PCO had significantly higher Knee Society Scores and better functional outcomes, whereas those with PCO reduction >2 mm had inferior outcomes ($p<0.001$).
Conclusions: Preservation of femoral PCO is associated with improved functional outcomes following PS TKA. As a modifiable surgical parameter, accurate femoral sizing and posterior condylar resection are essential to optimise postoperative knee function.

Keywords: Knee Society Score, Knee flexion, Osteoarthritis, Posterior condylar offset, Posterior condylar offset ratio, Posterior-stabilised, Total knee arthroplasty

INTRODUCTION

Osteoarthritis of the knee is one of the most common causes of pain, disability and reduced quality of life among the elderly population worldwide. With increasing life expectancy and rising prevalence of obesity, the burden of knee osteoarthritis continues to grow, particularly in developing countries such as India. TKA has emerged as the definitive treatment for end-stage disease, offering reliable pain relief, correction of deformity and improved functional outcomes, with reported implant survivorship exceeding 90% at 10–15 years.[1,2] However, despite excellent radiological outcomes, a subset of patients remains dissatisfied due to limited postoperative knee flexion and functional impairment.[3] Multiple factors, including patient characteristics, surgical technique, implant design and restoration of normal knee biomechanics influence postoperative knee function following TKA. Among these, achieving optimal femoral rollback and maintaining a balanced flexion gap are critical for attaining adequate knee flexion. In Asian populations, where activities such as squatting and sitting

cross-legged are integral to daily living, even small reductions in knee flexion can significantly impact patient satisfaction and functional independence.[4,5] Therefore, identification of modifiable surgical factors that influence postoperative function is of considerable clinical importance.

Femoral PCO has been identified as a key anatomical parameter influencing knee kinematics. PCO refers to the posterior projection of the femoral condyles relative to the femoral shaft and plays a crucial role in facilitating femoral rollback during flexion. Reduction in PCO can tighten the flexion gap, limit posterior femoral translation and impair quadriceps efficiency, thereby reducing postoperative knee flexion.[6,7] In PS TKA, although femoral rollback is facilitated by a cam–post mechanism, restoration of posterior femoral geometry remains essential for optimal function.[8]

Previous studies evaluating the relationship between PCO and functional outcomes have reported conflicting results, with some demonstrating a positive correlation between preservation of PCO and improved flexion, while others suggest that knee flexion is influenced by multiple interacting variables rather than a single anatomical factor.[9,10] Furthermore, most available evidence is derived from Western populations, with limited data focusing on posterior-stabilized, fixed-bearing designs in the Indian context. Therefore, the present study aims to evaluate the effect of changes in femoral posterior condylar offset on functional outcomes following posterior-stabilized primary total knee arthroplasty.

METHODS

Study design and setting

This prospective observational study was conducted in the Department of Orthopaedics at a tertiary care centre between April 2024 and September 2025.

Study population

A total of 21 patients were diagnosed with primary knee osteoarthritis.

Inclusion criteria

Age between 50 and 80 years, radiological diagnosis of Kellgren–Lawrence grade 3 or 4 osteoarthritis. Patients undergoing posterior-stabilized, fixed-bearing primary total knee arthroplasty.

Exclusion criteria

Inflammatory arthritis, previous knee surgery or revision arthroplasty, severe bone loss or deformity requiring constrained implants, inadequate radiographs for assessment.

Surgical technique

All patients underwent posterior-stabilised, fixed-bearing total knee arthroplasty using a standard medial parapatellar approach. The posterior cruciate ligament was sacrificed in all cases. Femoral preparation was performed using standard instrumentation with attention to appropriate femoral component sizing and posterior condylar resection to maintain flexion gap balance. All procedures were performed by experienced orthopaedic surgeons following a uniform surgical protocol.

Radiological assessment

Preoperative and postoperative true lateral radiographs of the knee were obtained. Femoral PCO was measured as the maximum perpendicular distance from the posterior cortex of the femoral shaft to the posterior margin of the femoral condyle. Measurements were performed using standardised radiographic techniques to minimize variability (Figure 1).

Outcome measures

Patients were evaluated clinically using the knee society score (KSS). Assessments were performed preoperatively and at 6 weeks, 3 months and finally 6 months postoperatively.

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 26 software. Continuous variables were expressed as mean±standard deviation. Comparisons between preoperative and postoperative values were performed using paired statistical tests. The association between changes in posterior condylar offset and functional outcomes was analysed using correlation and comparative statistical methods. A p value of <0.05 was considered statistically significant.

RESULTS

Socio-demographic characteristics of patients

A total of 21 patients were included in the study. The mean age of the study population was 66.81±5.56 years, with the majority of patients belonging to the 60–70 years age group. There was a slight predominance of female patients compared to males. Most patients had a long duration of symptoms, with a mean duration of 7.86±3.52 years, indicating chronic and advanced disease at presentation. The majority of patients presented with advanced osteoarthritis (Kellgren–Lawrence grade 4). Regarding laterality, both knees were affected, with a slight predominance of unilateral involvement. The most common preoperative deformity observed was varus deformity, consistent with medial compartment osteoarthritis (Table 1).

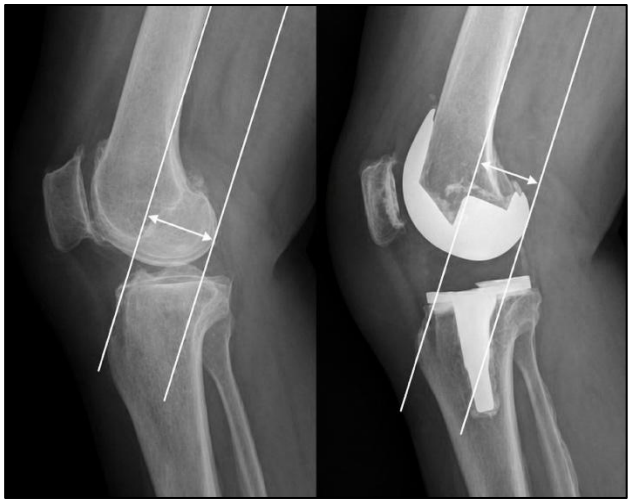

Figure 1: Baseline demographic and clinical characteristics of the study population.

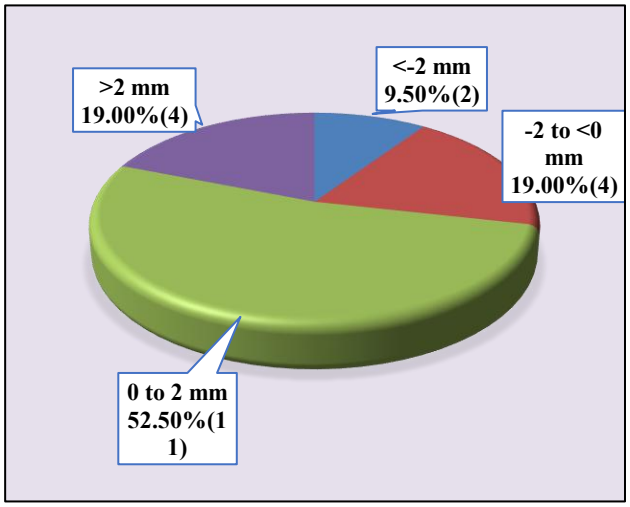

Figure 2: Distribution of study population based on change in posterior condylar offset.

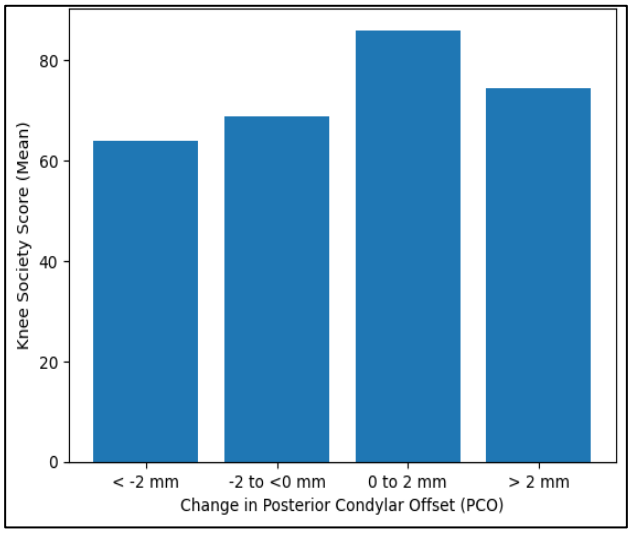

Figure 3: KSS vs PCO change in 6-month follow-up.

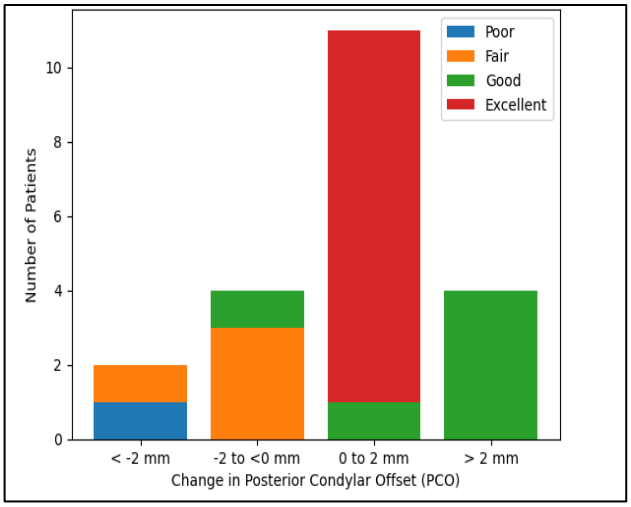

Figure 4: Distribution of functional outcomes (KSS) across PCO change categories.

Distribution of study population based on change in posterior condylar offset

Postoperatively, the majority of patients (52.4%-11 patients) demonstrated a change in posterior condylar offset (PCO) between 0 and 2 mm, indicating preservation or minimally increased PCO following surgery. A smaller proportion of patients showed a mild reduction in PCO (−2 to <0 mm) in 19.0% (4 patients), while an equal percentage (19.0% - 4 patients) exhibited an increase greater than 2 mm. Only 9.5% (2) of patients had a marked reduction in PCO (<- 2 mm) (Figure 2).

Effect of change in posterior condylar offset on knee society score at 6 months follow-up

The KSS demonstrated a statistically significant variation across different categories of change in PCO. Patients with a marked reduction in PCO (<-2 mm) had the lowest mean KSS (64.00±7.07), indicating poorer functional outcomes. Slightly higher scores were observed in patients with mild reduction in PCO (−2 to <0 mm) (68.75±4.11) (Figure 3). The highest mean KSS was observed in patients with preservation or minimally increased PCO (0–2 mm) (86.00±4.00), suggesting optimal functional recovery when the posterior condylar offset is preserved or minimally increased. Patients with PCO increase >2 mm also demonstrated improved scores (74.50±3.42), although lower than the 0–2 mm group.

Overall, there was a statistically significant association between change in PCO and functional outcome ($F=28.422$, $p<0.001$), indicating that preservation of posterior condylar offset is associated with superior postoperative knee function. Association between change in posterior condylar offset (PCO) and outcome based on knee society score at 6 months. There was a statistically significant association between change in posterior condylar offset (PCO) and overall postoperative outcome

(χ^2=38.222, df=9, p<0.001). Patients with a marked reduction in PCO (<−2 mm) demonstrated poor outcomes, with 50% classified as poor and 50% as fair and none achieving good or excellent results. In the −2 to <0 mm group, the majority of patients (75.0%) had fair outcomes, while only 25.0% achieved good outcomes. In contrast, patients with preserved or minimally increased PCO (0–2 mm) showed the most favourable results, with 90.9% achieving excellent outcomes and the remaining 9.1% classified as good. Similarly, patients with PCO increases of >2 mm demonstrated uniformly good outcomes (100% good) (Figure 4). Overall, 47.6% of patients achieved excellent outcomes, predominantly in the group with minimal PCO change, highlighting the importance of preserving posterior condylar offset for optimal functional recovery.

Table 1: Baseline demographic and clinical characteristics of the study population.

Variables	N (%)
Age (in years), mean±SD	66.81±5.56
Age group (in years)	
50–60	3 (14.3)
61–70	13 (61.9)
71–80	5 (23.8)
Gender	
Male	10 (47.6)
Female	11 (52.4)
Duration of symptoms (years), mean±SD	7.86±3.52
Laterality	
Right knee	11 (52.4)
Left knee	10 (47.6)
Kellgren–Lawrence grade	
Grade III	6 (28.6)
Grade IV	15 (71.4)
Preoperative deformity	
Varus	16 (76.2)
Valgus	5 (23.8)
Fixed flexion deformity	8 (38.1)

DISCUSSION

The present prospective observational study evaluated the influence of femoral PCO on functional outcomes following posterior-stabilized, fixed-bearing total knee arthroplasty. The findings demonstrated that the majority of patients had preservation or minimal increase in PCO (0–2 mm) and this group achieved the most favourable functional outcomes, with significantly higher knee society scores (KSS) and a greater proportion of excellent results. In contrast, patients with a reduction in PCO greater than 2 mm exhibited inferior outcomes, including lower KSS and poorer categorical results. These findings reinforce the concept that restoration of posterior femoral geometry plays a crucial role in optimizing functional recovery following TKA.

From a biomechanical perspective, posterior condylar offset is a key determinant of femoral rollback during knee flexion. Adequate PCO maintains the posterior femoral contour, allowing smooth posterior translation of the femur on the tibia and preventing early impingement of the posterior femur on the tibial insert. Reduction in PCO effectively tightens the flexion gap, limits rollback and increases quadriceps force requirements, thereby impairing knee flexion and functional performance. Johal et al introduced the posterior condylar offset ratio as a reliable radiographic parameter, while Soda et al, demonstrated that preservation of this ratio correlates with improved flexion following posterior-stabilised TKA.[11,12] Similarly, Arabori et al reported that decreased PCO is associated with reduced postoperative knee flexion in both cruciate-retaining and posterior-stabilised designs.[13] The present study findings are consistent with these observations, as patients with reduced PCO had inferior functional outcomes.

The present study also highlights that the relationship between PCO and functional outcome is not merely dependent on preservation versus loss, but rather on the magnitude of change. Patients with minimal change in PCO (0–2 mm) achieved the best outcomes, suggesting that maintaining near-native posterior femoral geometry is critical. This is supported by Bauer et al who demonstrated that decreased PCO adversely affects knee flexion in cruciate-sacrificing TKA.[14] Clement et al further established that PCO is an independent predictor of functional outcome even in revision arthroplasty.[15] More recently, Zhong et al suggested that optimal clinical outcomes are achieved when PCO variation is maintained

within a narrow range, which aligns with the present observation that minimal change (0–2 mm) yields the best results.[16] More recent evidence further supports this concept. A 2024 study demonstrated that PCO variation is significantly associated with functional outcomes, with an optimal range of approximately 2.85 mm for achieving favourable clinical results.[16,19]

Despite these consistent findings, the literature remains heterogeneous. Chang et al reported that although posterior referencing techniques better preserve PCO, changes in PCO did not significantly influence postoperative range of motion in posterior-stabilised TKA.[17] Similarly, Panciera et al found no significant association between posterior condylar offset ratio and functional outcomes.[18] A recent meta-analysis comparing anterior and posterior referencing techniques reported that although posterior referencing better preserves PCO, this does not always translate into significant differences in clinical outcomes, highlighting the multifactorial nature of postoperative knee function.[20]

These conflicting results may be explained by differences in study design, implant characteristics and patient populations. In posterior-stabilised TKA, the cam–post mechanism is designed to substitute for posterior cruciate ligament function and facilitate femoral rollback. This mechanism may partially compensate for variations in PCO, thereby reducing its apparent influence in some studies. Additionally, factors such as tibial slope, soft-tissue balancing, joint line restoration and rehabilitation protocols also contribute to postoperative function, potentially confounding the isolated effect of PCO.

An important clinical implication of the present study is that PCO is a surgically modifiable parameter and should be carefully considered during femoral preparation. Excessive posterior condylar resection, improper femoral component sizing or anterior referencing techniques may lead to unintended reduction in PCO. Conversely, appropriate femoral sizing and posterior referencing can help preserve or restore PCO, thereby optimizing flexion gap balance. Surgeons should aim to avoid both excessive reduction and overstuffing of the posterior condyles, as both extremes may adversely affect knee kinematics. The findings of this study suggest that maintaining PCO within a physiological range is more important than simply increasing it. Recent imaging-based studies have also demonstrated that posterior condylar offset significantly influences knee flexion mechanics and cartilage relationships, further reinforcing its role in postoperative functional recovery.[21] Another important aspect highlighted by this study is its relevance to the Indian population. Functional demands in this population, including squatting and sitting cross-legged, require greater degrees of knee flexion compared to Western populations. Therefore, even small reductions in postoperative flexion can significantly affect patient satisfaction. Preservation of PCO may therefore have greater clinical importance in this setting and surgical strategies should be adapted accordingly to meet these functional requirements.

The present study has certain limitations. The sample size was relatively small, which may limit statistical power and generalizability. The follow-up period was limited to 6 months, which may not fully reflect long-term functional outcomes and implant performance. Additionally, the study was conducted at a single centre and measurements were based on plain radiographs, which may be subject to observer variability.

Furthermore, several potential confounding factors may have influenced the observed functional outcomes. These include patient-related factors such as age, body mass index, preoperative range of motion, muscle strength and comorbidities; surgical factors such as implant positioning, tibial slope, joint line restoration and soft-tissue balancing; as well as postoperative variables including rehabilitation protocols and patient compliance. As these variables were not independently controlled or analysed, their potential influence on postoperative knee function cannot be excluded. Despite these limitations, the study demonstrates a strong and statistically significant association between PCO preservation and functional outcomes, supporting its clinical relevance.

CONCLUSION

The present study demonstrates that femoral PCO is an important determinant of functional outcome following posterior-stabilised, fixed-bearing total knee arthroplasty. Preservation or minimal increase in PCO (0–2 mm) was associated with significantly better Knee Society Scores and a higher proportion of excellent outcomes, whereas a reduction in PCO greater than 2 mm resulted in inferior functional results. These findings emphasise that restoration of posterior femoral geometry plays a crucial role in achieving optimal knee function after TKA. As PCO is a surgically modifiable parameter, meticulous attention to femoral component sizing, accurate posterior condylar resection and appropriate flexion gap balancing are essential to optimize postoperative outcomes. Further studies with larger sample sizes and longer follow-up are required to validate these findings and to better define the optimal range of PCO restoration in total knee arthroplasty.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Jishnu Krishnan K, Abdul Asraf V, Saithalikutty Chemmala S, Mohamed Shakeeb KU. Influence of femoral posterior condylar offset on functional outcomes following posterior-stabilized fixed bearing total knee arthroplasty; a prospective observational study. Int J Res Orthop 2026;12:1049-54.