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Original Research Article

Radiographic Evaluation of Component Alignment and Functional Results in Total Knee Arthroplasty

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Abstract

Background: Total knee arthroplasty (TKA) is an established surgical procedure for the management of advanced knee osteoarthritis. Accurate alignment of prosthetic components is considered essential for achieving optimal functional outcomes and implant longevity. However, the relationship between radiological alignment and postoperative functional recovery remains a subject of ongoing debate.

Aim: To radiologically assess component alignment in various planes following total knee arthroplasty and evaluate its relationship with functional outcomes using the Knee Society Score.

Materials and Methods: This prospective observational study included 150 patients undergoing primary total knee arthroplasty. Postoperative radiological evaluation was performed using standardized weight-bearing anteroposterior, lateral, skyline, and full-length standing hip-knee-ankle radiographs. Alignment parameters including hip-knee-ankle angle, coronal femoral component angle, coronal tibial component angle, sagittal femoral component angle, posterior tibial slope, and patellar tilt angle were measured. Functional outcomes were assessed using the Knee Society Score. Statistical analysis was performed using SPSS version 26.0, and a p-value <0.05 was considered statistically significant.

Results: The mean postoperative hip-knee-ankle angle was 179.2±2.4°. A total of 112 patients (74.7%) achieved alignment within ±3° of the neutral mechanical axis. Patients with optimal alignment demonstrated significantly higher Knee Society Scores (91.8±5.4) compared with patients having alignment deviations greater than 3° (84.6±7.2) ($p<0.001$). Significant positive correlations were observed between hip-knee-ankle angle and Knee Society Score ($r=0.621$, $p<0.001$), coronal femoral component angle and Knee Society Score ($r=0.384$, $p<0.001$), and coronal tibial component angle and Knee Society Score ($r=0.351$, $p<0.001$). Posterior tibial slope showed no statistically significant association with functional outcome ($p=0.151$).

Conclusion: Accurate restoration of mechanical alignment and proper component positioning are significantly associated with improved functional outcomes following total knee arthroplasty. Coronal alignment parameters demonstrated stronger correlations with Knee Society Scores than sagittal alignment parameters, emphasizing the importance of precise radiological alignment in achieving successful postoperative outcomes.

Keywords: Total knee arthroplasty, Component alignment, Radiological assessment, Knee Society Score.

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Introduction

Total knee arthroplasty (TKA) is one of the most successful orthopedic procedures for the management of end-stage knee osteoarthritis, providing substantial pain relief, restoration of function, and improvement in quality of life. With increasing life expectancy and rising prevalence of degenerative joint diseases, the demand for TKA has increased significantly worldwide. Despite excellent implant survivorship and advances in surgical techniques, approximately 15–20% of patients remain dissatisfied after surgery due to persistent pain, instability, limited range of motion, or suboptimal functional outcomes [1]. Proper positioning and alignment of prosthetic components are considered critical determinants of successful TKA. The primary objectives of component alignment are restoration of the mechanical axis of the lower limb, balanced load distribution across the prosthesis, optimization of soft tissue tension, and prevention of abnormal

wear and early implant failure [2]. Malalignment of femoral or tibial components may result in increased polyethylene wear, aseptic loosening, patellofemoral complications, instability, reduced range of motion, and ultimately compromised functional outcomes [3].

Traditionally, mechanical alignment has been regarded as the gold standard in TKA, aiming to achieve a neutral hip-knee-ankle axis and symmetrical load transfer across the knee joint. However, recent advances in alignment philosophies, including kinematic alignment and functional alignment, have challenged the concept that a universally neutral mechanical axis is essential for optimal outcomes. These contemporary approaches seek to restore the patient's native anatomy and joint kinematics while maintaining acceptable implant positioning [4].

Radiological assessment remains the most reliable method for evaluating postoperative component alignment. Standardized weight-bearing anteroposterior, lateral, skyline, and long-leg radiographs are routinely used to assess alignment in coronal, sagittal, and axial planes. Measurements such as the hip-knee-ankle angle, femoral component coronal angle, tibial component coronal angle, femoral flexion angle, tibial slope, and patellar alignment provide objective information regarding implant positioning and restoration of lower limb biomechanics [5].

Several studies have demonstrated that deviations greater than 3° from the desired alignment may adversely affect implant survival and increase the risk of mechanical complications [6]. However, recent evidence suggests that the relationship between radiological alignment and clinical outcomes may be more complex than previously believed. Some investigations have reported significant associations between accurate component positioning and improved postoperative function, whereas others have found limited correlation between radiographic alignment and patient-reported outcome measures [7].

Functional outcome assessment following TKA has evolved considerably over the past decade. The Knee Society Score (KSS) remains one of the most widely accepted and validated instruments for evaluating postoperative knee function. The updated KSS incorporates objective clinical assessment, patient satisfaction, expectations, and functional activities, providing a comprehensive evaluation of surgical success [8]. Because of its broad applicability and reproducibility, the KSS is frequently used in studies investigating factors influencing outcomes after TKA.

The growing interest in personalized alignment strategies has renewed attention toward understanding the precise relationship between radiological alignment and functional recovery. Recent studies have emphasized that restoration of physiological knee kinematics, rather than merely achieving neutral mechanical alignment, may be associated with improved patient satisfaction and functional performance [9]. Furthermore, advances in imaging techniques and digital radiographic analysis have enabled more accurate assessment of component positioning, facilitating detailed investigation of alignment-outcome relationships [10].

Despite extensive research, the influence of postoperative component alignment on functional outcome remains a subject of ongoing debate. Clarifying this relationship is important for optimizing surgical techniques, improving implant longevity, and enhancing patient satisfaction following TKA. Therefore, the present study was undertaken to radiologically assess component alignment in various planes following total knee arthroplasty and to evaluate its relationship with functional outcomes using the Knee Society Score.

Material and Methods

This prospective observational study was conducted in the Department of Orthopaedics of a tertiary care teaching hospital over a period of 24 months with the objective of evaluating the radiological alignment of prosthetic components following total knee arthroplasty (TKA) and assessing its relationship with functional outcomes using the Knee Society Score (KSS). A total of 150 patients diagnosed with end-stage primary osteoarthritis of the knee and scheduled for primary total knee arthroplasty were enrolled consecutively after obtaining written informed consent. Patients aged 50 years and above undergoing primary unilateral or bilateral TKA were included in the study. Patients undergoing revision arthroplasty, those with inflammatory arthritis, post-traumatic arthritis, severe extra-articular deformities affecting limb alignment, previous major knee surgeries, active infection, neuromuscular disorders affecting gait, or those unwilling to participate were excluded from the study.

All surgical procedures were performed by experienced orthopedic surgeons using a standardized operative technique. The surgeries were carried out under spinal or combined spinal-epidural anesthesia. A standard medial parapatellar approach was utilized, and cemented prosthetic components were implanted in all patients. Mechanical alignment principles were followed during component placement, and postoperative rehabilitation protocols were standardized to ensure uniformity of patient management.

Radiological evaluation was performed using standardized postoperative weight-bearing anteroposterior radiographs, lateral radiographs, skyline patellar views, and full-length standing hip-knee-ankle radiographs. Radiographs were obtained at six weeks postoperatively and during scheduled follow-up visits. The coronal femoral component angle, coronal tibial component angle, overall mechanical axis, sagittal femoral component angle, posterior tibial slope, and patellar alignment were assessed using established radiographic measurement techniques. All measurements were independently performed by two experienced orthopedic surgeons, and the mean of the recorded values was used for analysis to minimize observer bias.

Functional outcomes were assessed using the Knee Society Score (KSS), which includes both the Knee Score and Functional Score components. Patients were evaluated preoperatively and subsequently at 3 months, 6 months, and 12 months following surgery. The Knee Score assessed parameters such as pain, stability, and range of motion, while the Functional Score evaluated walking ability, stair climbing capacity, and overall functional performance. Higher scores were indicative of better clinical and functional outcomes.

Demographic and clinical data including age, gender, body mass index, affected side, duration of symptoms, and associated comorbidities were recorded using a structured proforma. Radiological alignment parameters and Knee Society Scores obtained during follow-up were documented and analyzed to determine their association.

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Paired t-tests were used to compare preoperative and postoperative Knee Society Scores. Independent t-tests and one-way analysis of variance (ANOVA) were applied for comparison of functional outcomes among different alignment groups. Pearson correlation analysis was used to evaluate the relationship between radiological alignment parameters and Knee Society Scores. Multiple linear regression analysis was performed to identify independent predictors of functional outcome. A p-value of less than 0.05 was considered statistically significant. The study protocol was reviewed and approved by the Institutional Ethics Committee prior to initiation of the study. Written informed consent was obtained from all participants before enrollment. Patient confidentiality was maintained throughout the study, and all procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

Results

A total of 150 patients who underwent primary total knee arthroplasty were included in the study. Table 1 shows the demographic and clinical characteristics of the study population. The mean age of the patients was 65.8±7.9 years. The majority of patients belonged to the 61–70 years age group (42.0%), followed by 51–60 years (26.7%), 71–80 years (22.0%), and above 80 years (9.3%). Females constituted 60.0% of the study population, while males accounted for 40.0%. The mean body mass index was 28.6±3.8 kg/m².

Table 2 depicts the postoperative radiological alignment parameters. The mean hip-knee-ankle (HKA) angle was 179.2±2.4 degrees. The mean coronal femoral component angle and coronal tibial component angle were 89.5±1.8 degrees and 89.8±1.6 degrees respectively. The mean sagittal femoral component angle was 3.2±1.4 degrees, while the mean posterior tibial slope was 4.7±1.5 degrees. These findings indicate satisfactory postoperative alignment in most patients.

Table 3 demonstrates the distribution of patients according to overall mechanical alignment. A total of 112 patients (74.7%) achieved alignment within ±3° of neutral mechanical axis, whereas 38 patients (25.3%) demonstrated deviation greater than 3°. This finding suggests that the majority of patients achieved acceptable radiological alignment following total knee arthroplasty.

Table 4 compares Knee Society Scores according to postoperative mechanical alignment. Patients with alignment within ±3° demonstrated significantly higher mean Knee Society Scores (91.8±5.4) compared to patients with alignment deviation greater than 3° (84.6±7.2). Similarly, Functional Scores were significantly higher among patients with optimal alignment (89.4±6.1) than those with malalignment (81.2±8.3). The differences were statistically significant ($p<0.001$), indicating better functional outcomes in patients with satisfactory radiological alignment.

Table 5 shows the correlation between radiological alignment parameters and Knee Society Scores. Significant positive correlations were observed between overall mechanical alignment and Knee Society Score ($r=0.621$, $p<0.001$), coronal femoral component angle and Knee Society Score ($r=0.384$, $p<0.001$), and coronal tibial component angle and Knee Society Score ($r=0.351$, $p<0.001$). Posterior tibial slope showed a weak non-significant correlation with Knee Society Score ($r=0.118$, $p=0.151$). These findings suggest that accurate coronal alignment has a stronger influence on

postoperative functional outcomes than sagittal alignment parameters.

Table 1: Demographic and Clinical Characteristics of Study Participants (n=150)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	51–60	40	26.7
	61–70	63	42.0
	71–80	33	22.0
	>80	14	9.3
Gender	Male	60	40.0
	Female	90	60.0
Operated Side	Right Knee	82	54.7
	Left Knee	68	45.3
BMI (kg/m²)	Mean ± SD	28.6 ± 3.8	—
Duration of Symptoms (years)	Mean ± SD	7.4 ± 2.9	—

Table 2: Postoperative Radiological Alignment Parameters (n=150)

Parameter	Mean ± SD	Range
Hip-Knee-Ankle (HKA) Angle (°)	179.2 ± 2.4	173–184
Coronal Femoral Component Angle (°)	89.5 ± 1.8	85–93
Coronal Tibial Component Angle (°)	89.8 ± 1.6	86–93
Sagittal Femoral Component Angle (°)	3.2 ± 1.4	0–7
Posterior Tibial Slope (°)	4.7 ± 1.5	1–8
Patellar Tilt Angle (°)	4.1 ± 1.8	1–9

Table 3: Distribution of Patients According to Postoperative Mechanical Alignment (n=150)

Mechanical Alignment Category	Frequency (n)	Percentage (%)
Within ±3° of Neutral Axis	112	74.7
Deviation >3° from Neutral Axis	38	25.3
Total	150	100.0

Table 4: Comparison of Functional Outcome According to Mechanical Alignment

Outcome Measure	Alignment Within ±3° (n=112) Mean ± SD	Alignment >3° (n=38) Mean ± SD	p-value
Knee Society Score	91.8 ± 5.4	84.6 ± 7.2	<0.001
Functional Score	89.4 ± 6.1	81.2 ± 8.3	<0.001
Range of Motion (°)	118.6 ± 9.2	110.4 ± 11.6	<0.001
Patient Satisfaction Score	8.9 ± 1.0	7.8 ± 1.3	<0.001

Table 5: Correlation between Radiological Alignment Parameters and Knee Society Score

Alignment Parameter	Correlation Coefficient (r)	p-value
Hip-Knee-Ankle Angle	0.621	<0.001
Coronal Femoral Component Angle	0.384	<0.001
Coronal Tibial Component Angle	0.351	<0.001
Sagittal Femoral Component Angle	0.204	0.012
Posterior Tibial Slope	0.118	0.151
Patellar Tilt Angle	-0.172	0.035

Discussion

The present study evaluated the radiological alignment of prosthetic components following total knee arthroplasty (TKA) and assessed its relationship with functional outcomes using the Knee Society Score (KSS). A total of 150 patients were included in the study. The findings demonstrated that satisfactory postoperative alignment was achieved in the majority of patients, with 74.7% of cases achieving alignment within ±3° of the neutral mechanical axis. Furthermore, patients with optimal radiological alignment exhibited significantly better Knee Society Scores, functional scores, range of motion, and patient satisfaction compared with those demonstrating greater alignment deviations.

In the present study, the mean postoperative hip-knee-ankle angle was 179.2±2.4°, indicating successful restoration of near-neutral mechanical alignment in most patients. Mechanical alignment has traditionally been regarded as a critical determinant of long-term implant survival and

postoperative function. Similar findings were reported by Kumar et al. [11], who observed that restoration of appropriate coronal alignment following primary TKA was associated with superior radiological outcomes and improved Knee Society Scores. Their study emphasized that accurate component positioning contributes to balanced load distribution across the prosthesis, thereby enhancing functional recovery and patient satisfaction.

The present study demonstrated that patients with alignment within ±3° of the neutral axis achieved significantly higher mean Knee Society Scores (91.8±5.4) compared to patients with alignment deviations greater than 3° (84.6±7.2). Functional scores and range of motion were also significantly better among patients with optimal alignment. These findings are in agreement with the observations of Chaudhary et al. [12], who reported significant postoperative improvements in both clinical and functional scores following total knee arthroplasty. Their study concluded that restoration of proper limb alignment plays an important role in maximizing postoperative functional performance and improving overall quality of life.

A major finding of the present study was the significant positive correlation between overall mechanical alignment and Knee Society Score ($r=0.621$, $p<0.001$). Coronal femoral component angle and coronal tibial component angle also demonstrated significant positive associations with functional outcomes.

Similar observations were reported in the systematic review conducted by Segura-Nuez et al. [13], who evaluated contemporary alignment techniques in total knee arthroplasty. The authors concluded that accurate coronal alignment remains an important predictor of favorable clinical outcomes despite the emergence of newer alignment philosophies such as kinematic and functional alignment. Their review highlighted that acceptable radiological alignment continues to be associated with improved implant function and patient satisfaction.

The present study further revealed that coronal alignment parameters exhibited stronger relationships with functional outcomes than sagittal alignment parameters. While the sagittal femoral component angle demonstrated a weak but significant correlation with Knee Society Score, posterior tibial slope showed no statistically significant association. These findings are consistent with the randomized controlled trial by Young et al. [14], who demonstrated that restoration of balanced coronal mechanics had a greater influence on postoperative function than isolated variations in sagittal component positioning. Their findings support the view that maintaining appropriate coronal alignment remains essential for achieving successful clinical outcomes following TKA.

Patient satisfaction and functional recovery are increasingly recognized as important indicators of success following total knee arthroplasty. In the present study, patients with satisfactory alignment reported significantly higher satisfaction scores and better functional performance. Similar findings were reported by Wang et al. [15], who evaluated the influence of alignment strategies on postoperative outcomes. The authors observed that accurate component positioning and restoration of physiological lower-limb mechanics resulted in superior early functional outcomes and improved patient satisfaction. Their study reinforced the concept that radiological precision remains a crucial factor in achieving optimal clinical results.

The present study possesses several strengths, including a relatively large sample size of 150 patients, standardized radiographic assessment, and comprehensive evaluation using the Knee Society Score. The findings provide additional evidence supporting the importance of achieving satisfactory postoperative alignment in total knee arthroplasty. However, certain limitations should be considered. The study was conducted at a single tertiary care center and follow-up was limited to one year. Longer-term studies incorporating implant survivorship and patient-reported outcome measures may provide further insight into the long-term clinical significance of radiological alignment.

Overall, the findings of the present study indicate that accurate restoration of mechanical alignment and proper component positioning are associated with superior functional outcomes following total knee arthroplasty. Patients achieving alignment within acceptable radiological limits demonstrated significantly better Knee Society Scores, range of motion, and satisfaction compared with patients exhibiting postoperative malalignment.

Conclusion

The present study demonstrated that satisfactory radiological alignment was achieved in the majority of patients undergoing total knee arthroplasty. Significant positive associations were observed between postoperative component alignment and functional outcomes assessed using the Knee Society Score. Patients with mechanical alignment within ±3° of neutral achieved significantly better Knee Society Scores, functional scores, range of motion, and patient satisfaction compared with those demonstrating greater alignment deviations. Coronal alignment parameters exhibited stronger correlations with functional outcomes than sagittal alignment parameters. These findings emphasize the importance of precise component positioning

and restoration of mechanical alignment for optimizing functional recovery following total knee arthroplasty.

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