

ORIGINAL ARTICLE

Effect of Postoperative Sagittal Component Alignment on Functional Outcome and Patient Satisfaction Following Primary Total Knee Arthroplasty

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ABSTRACT

Background: Sagittal component alignment is one of the key factors that affects knee biomechanics after total knee arthroplasty (TKA), and its correlation with functional outcome and patient satisfaction is not well established.

Objective: Primary TKA patients who have a more normal sagittal component alignment will have a better functional outcome and satisfaction.

Material and Methods: Prospective Observational Analytical study was done in department of Orthopaedics Hayatabad Medical Complex Peshawar from August 2022 to January 2023. Patients were included in the study by consecutive sampling, and a total of 120 patients who were undergoing primary unilateral TKA were selected. Femoral component sagittal alignment, posterior tibial slope and posterior condylar offset were evaluated on postoperative lateral knee radiographs. Functional outcome was determined by the Hospital for Special Surgery Knee Score, which was assessed preoperatively and 6 months postoperatively. At six months patient satisfaction was also evaluated. Descriptive and inferential statistical analysis, correlation analysis and multivariable regression analysis were conducted.

Results: The mean age was 64.2 ± 8.7 years. Mean HSS score improved from 48.6 ± 7.9 preoperatively to 86.4 ± 8.2 at six months ($p < 0.001$). Femoral alignment sagittal alignment was in the target range in 78 (65.0%) patients and posterior tibial slope was in the target range in 81 (67.5%) patients. Patients with the femoral component range within the target range scored higher in the HSS post-op scores than those with the femoral component out of the target range (89.1 ± 6.7 vs. 81.4 ± 9.4 , $p < 0.001$). Posterior tibial slope was found to be similar. Overall, 91 (75.8%) patients were happy or very happy with surgery.

Conclusion: Sagittal component alignment was associated with better functional outcome and patient satisfaction after primary TKA.

Keywords: are total knee arthroplasty (TKA), sagittal alignment and the posterior tibial slope.

INTRODUCTION

Total knee arthroplasty (TKA) is a well-established procedure for the treatment of end-stage knee osteoarthritis (OA) and its main objectives are pain relief, restoration of the knee function and improvement of quality of life. Although the post-operative results are mostly good, a percentage of patients still have pain, loss of function or dissatisfaction following surgery. It is believed that the placement of the implant, and restoration of the proper knee biomechanics, play an important role in the recovery following surgery. While there has been a great deal of focus on coronal component alignment, there is growing evidence that sagittal component alignment has an impact on knee kinematics and functional performance after TKA as well^{1,2}.

Sagittal alignment has multiple parameters measured on the radiographs: flexion of the femoral component, slope of the tibial component, posterior tibial slope, and posterior condylar offset. These parameters will influence the flexion and extension gaps as well as the relationship between the femoral and tibial components during knee extension and flexion and may affect the gap. Consequently, the change in the positioning of the sagittal components can affect the kinematics at each joint, tension in the ligaments, patellofemoral mechanics, and the forces needed for knee motion. Biomechanical studies have shown that changing the flexion angle of the femoral component is capable of altering tibiofemoral translation, quadriceps load and patellofemoral contact forces³.

Posterior tibial slope is especially relevant when it comes to the sagittal geometry of the reconstructed knee. Correct tibial slope correction can affect the posterior rollback, posterior flexion, tension of the ligaments and the stability of the knee. Some clinical studies have demonstrated that the reconstruction of the posterior

tibial slope in a relatively narrow range is correlated with better postoperative ROM and functional scores in CR-TKA⁴. But the optimum postoperative slope can differ depending on implant design, the status of the cruciate ligaments, pre-operative anatomy and the alignment philosophy followed during the TKA procedure.

Another key factor to the knee mechanics after surgery is the sagittal orientation of the femur. A large amount of flexion or extension of the femoral component can change the flexion-extension gap and influence the patellofemoral and tibiofemoral relationships. In the clinical study, a higher position of the femoral component in the flexed direction was correlated with a higher number of patients with persistent postoperative flexed position, thus indicating that sagittal positioning may have clinically relevant extension consequences after surgery⁵. In contrast, biomechanical studies have demonstrated that while small changes in the position of the femur can have a significant impact on the kinematics of the knee, it can also have an impact on the magnitude of some quadriceps and patellofemoral forces³.

Posterior condylar offset is also important during sagittal reconstruction as it plays a role in the flexion arc and in the rollback of the femur. The posterior condylar offset and the tibial slope could be interacting rather than independent – the combination of these may affect the postoperative knee flexion⁶. However, there has not been a consistent clinical evidence for posterior condylar offset. There was no significant relationship between the change in posterior condylar offset and postoperative ROM or PROMs in a large retrospective series of 970 posterior-stabilized TKAs, further underlining the complexity of functional outcomes after TKA⁷.

There was also recent clinical research that further supports the correlation between sagittal component alignment and functional outcome and patient satisfaction. In a prospective cohort study of postoperative sagittal alignment of the femoral and tibial components, there was significant improvement in the American Knee Society and Oxford Knee Scores, and a correlation between

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the sagittal component positioning with clinical outcomes⁸. Likewise, a recent large study of modern TKAs investigated the correlation of femoral flexion and posterior tibial slope with patient-reported outcomes and determined ranges of alignment that correlated with clinically meaningful postoperative improvements. These results indicate that the sagittal position should not only be a technical parameter in the radiographic reconstruction process but an important element of patient-specific reconstruction⁹.

Many factors affect the satisfaction experienced by patients following TKA, with pain, functional outcome, expectations, preoperative status, implant-specific variables, and re-establishment of physiological knee kinematics. A few studies have examined alignment strategies and found varying patient-reported outcomes and patient satisfaction based on how well native knee anatomy and alignment is replicated, with some evidence suggesting that there is no single, universal target sagittal alignment¹⁰. Moreover, dissatisfaction can be maintained after normal X-rays were obtained, suggesting that sagittal component positioning needs to be considered along with soft-tissue balance, component rotation, coronal positioning, rehabilitation and patient-related factors.

Thus, postoperative sagittal component alignment may be a clinically relevant parameter for functional recovery and satisfaction following primary TKA. But the link between specific sagittal radiographic parameters and patient-centered outcomes is not fully characterized, especially in a clinical setting. The purpose of the present study was, therefore, to assess if there was an association between postoperative sagittal component alignment and functional outcome and patient satisfaction after primary total knee arthroplasty. The aim of this study was to assess if the postoperative sagittal alignment of the femoral component, sagittal tibial slope and associated parameters are correlated with functional outcome and patient satisfaction after primary TKA.

MATERIAL AND METHODS

A prospective observational analytical study was carried out in the Department of Orthopaedics, Hayatabad Medical Complex, Peshawar for six months from August 2022 to January 2023. The study aimed to assess the relationship between the postoperative sagittal component alignment and functional outcomes and patient satisfaction after primary total knee arthroplasty (TKA).

Patients were consecutively sampled for a total of 120 patients who underwent primary unilateral TKA. Patients who had complete clinical evaluations and adequate preoperative and postoperative radiographs and who had undergone primary knee arthroplasty for end-stage knee osteoarthritis at least 18 years of age were included. Patients who were undergoing revision TKA, bilateral simultaneous TKA, TKA for acute trauma, fracture, inflammatory arthritis, active infection, malignancy or had inadequate radiographic or clinical data were excluded.

Demographic and clinical data such as age, sex, body mass index (BMI), operated side, underlying diagnosis, and pertinent comorbidities were documented. All patients had primary total knee arthroplasty (TKA) performed in the conventional surgical approach of the Orthopaedics Department. All of the details of the surgical procedure, prosthesis type and design were recorded. Post-operative rehabilitation was performed with the departmental protocol.

Standardized lateral knee radiographs following TKA were used to assess postoperative radiography. The sagittal component alignment was evaluated using the sagittal angle of the femoral component and the posterior tibial slope. The sagittal angle between the femur shaft and the sagittal axis of the femoral component was measured. In the study, the posterior tibial slope was determined by measuring the angle formed by the tibial component surface or plateau and the mechanical or anatomical axis of the tibia. Posterior condylar offset and posterior condylar offset ratio were also evaluated, if available. Radiographic measurements were taken in degrees or mm, whichever was applicable.

The patients were clinically evaluated before surgery and then at the 6-month mark after surgery. Functional outcome was determined based on the Hospital for Special Surgery (HSS) Knee Score or Knee Society Score as appropriate to the validated assessment tool that was used in the study. Assessment comprised pain, functional activity, range of motion, stability, and other pertinent clinical parameters. A standard patient satisfaction questionnaire was used to determine patient satisfaction at the six-month mark. Patients were divided by the extent of sagittal component alignment, and values of sagittal component alignment that deviated from the described target ranges were compared with values that matched the target ranges.

All the collected data was entered and analysed with IBM SPSS Statistics. Demographic, clinical, radiographical and functional features were summarized using descriptive statistics. Means and standard deviations, or medians with interquartile ranges, were used to describe continuous variables with normally distributed data, or those that were not normally distributed, respectively. All categorical variables such as sex, operated side, alignment categories and satisfaction categories were reported in terms of frequencies and percentages.

Inferential statistical analysis was conducted to identify the relationship between postoperative SCA and clinical outcomes. Normally distributed continuous variables were compared between 2 groups using the independent-samples t-test and non-normally distributed variables were compared using the Mann-Whitney U test. Comparisons were made between more than two groups of alignment, normally distributed data was analyzed by 1-way analysis of variance (ANOVA), and non-parametric data were analyzed by Kruskal-Wallis test. The chi-square test and Fisher's exact test were used to determine associations with categorical variables, as appropriate. Relationships between normally distributed continuous radiographic and functional variables were evaluated using Pearson's correlation coefficient and non-normally distributed variables were analyzed with Spearman's rank correlation coefficient.

Multiple linear regression analysis was used to find out if sagittal alignment parameters were independent predictors of functional outcome after controlling for potential confounding factors (age, sex, BMI and preoperative functional score). A binary logistic regression analysis was conducted to determine factors independently associated with patient dissatisfaction. Beta coefficients or odds ratios with 95% confidence intervals were reported. A p value < 0.05 was deemed statistically significant.

The study was conducted with obtaining ethical permission from the appropriate institutional ethical committee of Hayatabad Medical Complex. Written informed consent was obtained from all participants. All data collected were kept confidential and only used for research.

RESULTS

A total of 120 patients who underwent primary total knee arthroplasty during the study period from January 2023 to June 2023 were included in the analysis. The mean age of the participants was 64.2 ± 8.7 years, ranging from 45 to 82 years. There were 71 (59.2%) male and 49 (40.8%) female patients. The mean BMI was 27.8 ± 4.1 kg/m². The right knee was operated on in 63 (52.5%) patients, while 57 (47.5%) underwent surgery on the left knee. Primary osteoarthritis was the indication for surgery in 105 (87.5%) patients, while 15 (12.5%) had secondary osteoarthritis. The mean preoperative HSS score was 48.6 ± 7.9 , indicating substantial functional limitation before surgery (Table 1).

Postoperative radiographic assessment demonstrated variation in sagittal component alignment. The mean sagittal femoral component angle was $3.8^\circ \pm 2.4^\circ$, while the mean posterior tibial slope was $6.1^\circ \pm 2.2^\circ$. The mean posterior condylar offset was 28.7 ± 3.9 mm. Based on the predefined alignment criteria, 78 (65.0%) patients had femoral component sagittal alignment within the target range, whereas 42 (35.0%) had alignment outside the target range. Posterior tibial slope was within

Table 1: Demographic and Clinical Characteristics of the Study Participants (n = 120)

Variable	Category/Statistic	n	%
Age (years)	Mean $\pm$ SD	64.2 $\pm$ 8.7	—
Age (years)	40–49	7	5.8
	50–59	25	20.8
	60–69	52	43.3
	70–79	29	24.2
	≥ 80	7	5.8
Sex	Male	71	59.2
	Female	49	40.8
BMI (kg/m ²)	Mean $\pm$ SD	27.8 $\pm$ 4.1	—
BMI category	<25	31	25.8
	25–29.9	62	51.7
	≥ 30	27	22.5
Operated side	Right	63	52.5
	Left	57	47.5
Diagnosis	Primary osteoarthritis	105	87.5
	Secondary osteoarthritis	15	12.5

Table 2: Postoperative Sagittal Radiographic Parameters

Radiographic parameter	Mean $\pm$ SD	Target/Category	n	%
Femoral component sagittal angle	3.8 $\pm$ 2.4°	—	—	—
Femoral component alignment	—	Within target range	78	65.0
	—	Outside target range	42	35.0
Posterior tibial slope	6.1 $\pm$ 2.2°	—	—	—
Posterior tibial slope	—	Within target range	81	67.5
	—	Outside target range	39	32.5
Posterior condylar offset	28.7 $\pm$ 3.9 mm	—	—	—
Posterior condylar offset ratio	0.87 $\pm$ 0.09	—	—	—
Combined sagittal alignment	—	Both within target range	70	58.3
	—	One or both outside target range	50	41.7

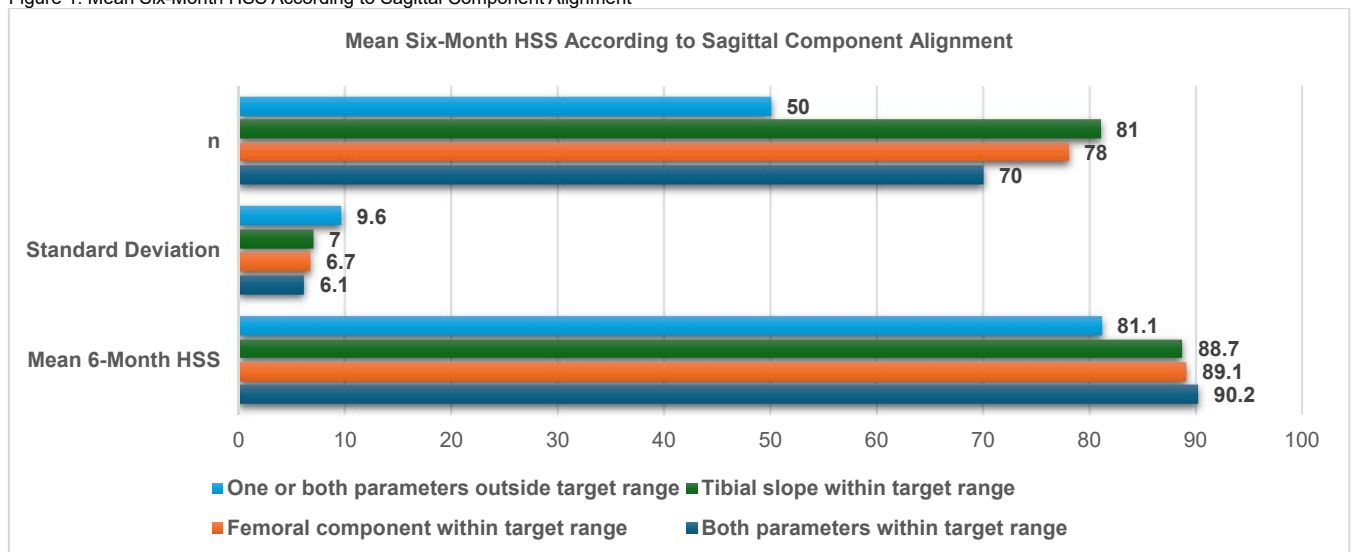
Table 3: Association Between Sagittal Component Alignment and Functional Outcome

Alignment parameter	n	Preoperative HSS, mean $\pm$ SD	6-month HSS, mean $\pm$ SD	Mean improvement	p-value
Femoral component within target	78	48.9 $\pm$ 7.7	89.1 $\pm$ 6.7	40.2 $\pm$ 8.8	<0.001
Femoral component outside target	42	48.1 $\pm$ 8.3	81.4 $\pm$ 9.4	33.3 $\pm$ 9.8	<0.001
Tibial slope within target	81	48.8 $\pm$ 7.8	88.7 $\pm$ 7.0	39.9 $\pm$ 8.9	<0.001
Tibial slope outside target	39	48.2 $\pm$ 8.2	81.6 $\pm$ 9.5	33.4 $\pm$ 10.1	<0.001
Both parameters within target	70	49.0 $\pm$ 7.6	90.2 $\pm$ 6.1	41.2 $\pm$ 8.3	<0.001
One or both outside target	50	48.0 $\pm$ 8.3	81.1 $\pm$ 9.6	33.1 $\pm$ 10.3	<0.001
Overall	120	48.6 $\pm$ 7.9	86.4 $\pm$ 8.2	37.8 $\pm$ 9.6	<0.001

Table 4: Association Between Sagittal Alignment and Patient Satisfaction

Alignment parameter	n	Satisfied/Very satisfied n (%)	Neutral/Dissatisfied n (%)	p-value
Femoral component within target	78	64 (82.1)	14 (17.9)	0.032
Femoral component outside target	42	27 (64.3)	15 (35.7)	—
Tibial slope within target	81	65 (80.2)	16 (19.8)	0.048
Tibial slope outside target	39	26 (66.7)	13 (33.3)	—
Both parameters within target	70	60 (85.7)	10 (14.3)	0.009
One or both outside target	50	31 (62.0)	19 (38.0)	—
Overall	120	91 (75.8)	29 (24.2)	—

Figure 1: Mean Six-Month HSS According to Sagittal Component Alignment



the predefined target range in 81 (67.5%) patients and outside the target range in 39 (32.5%). Overall, 70 (58.3%) patients had both femoral component alignment and posterior tibial slope within the predefined target ranges (Table 2).

Significant improvement in functional outcome was observed six months after surgery. The mean HSS score increased from 48.6 $\pm$ 7.9 preoperatively to 86.4 $\pm$ 8.2 postoperatively, representing a mean improvement of 37.8 $\pm$ 9.6 points ($p < 0.001$).

Patients with femoral component sagittal alignment within the target range had a higher mean postoperative HSS score than those with alignment outside the target range (89.1 $\pm$ 6.7 vs. 81.4 $\pm$ 9.4; $p < 0.001$). Similarly, patients with posterior tibial slope within the target range demonstrated higher postoperative HSS scores compared with patients outside the target range (88.7 $\pm$ 7.0 vs. 81.6 $\pm$ 9.5; $p < 0.001$). Patients with both sagittal parameters within

the target range achieved the highest mean postoperative HSS score of 90.2 ± 6.1 (Table 3).

Patient satisfaction at six months was also significantly associated with postoperative sagittal alignment. Overall, 91 (75.8%) patients reported being satisfied or very satisfied with the outcome of surgery, while 29 (24.2%) reported being neutral or dissatisfied. Among patients with femoral component alignment within the target range, 64 (82.1%) reported satisfaction compared with 27 (64.3%) among those outside the target range ($p = 0.032$). Similarly, satisfaction was reported by 65 (80.2%) patients with tibial slope within the target range compared with 26 (66.7%) patients with tibial slope outside the target range ($p = 0.048$). Patients with both sagittal parameters within the target range had the highest satisfaction rate, at 85.7% (Table 4).

Correlation analysis demonstrated significant relationships between sagittal component alignment and postoperative functional outcome. Greater deviation of the femoral component from the predefined sagittal target was associated with a lower postoperative HSS score (Spearman's $\rho = -0.42$, $p < 0.001$). Similarly, greater deviation in posterior tibial slope was inversely correlated with postoperative HSS score (Spearman's $\rho = -0.36$, $p < 0.001$). Patient satisfaction was also positively associated with postoperative HSS score (Spearman's $\rho = 0.51$, $p < 0.001$). In multiple linear regression analysis, femoral component sagittal deviation and tibial slope deviation remained independently associated with postoperative HSS after adjustment for age, sex, BMI, and preoperative HSS. In binary logistic regression, patients with both sagittal parameters within the target range had higher adjusted odds of being satisfied with their surgical outcome (Table 5).

DISCUSSION

In the present study, the authors examined the relationship between the SCA and functional outcome and patient satisfaction after primary TKA. The results showed significant post-operative improvement in functional status with a mean HSS score from 48.6 ± 7.9 preoperatively to 86.4 ± 8.2 at six months. Importantly, the patient outcomes (postoperative functional scores and satisfaction) were better for patients with the femur and tibia within the sagittal target ranges than for patients with the femur and tibia outside of the sagittal target ranges. The results are consistent with the hypothesis that sagittal component positioning is an important factor in the reconstruction of TKA and could be used to aid recovery after surgery.

The mean postoperative SFCA in this study was $3.8^\circ \pm 2.4^\circ$; 65.0% of the patients had a postoperative SFCA within the range of 3° to 5° . The mean postoperative HSS score for patients in the target range was significantly higher than for those not in the target range. The results are similar to earlier biomechanical and clinical studies suggesting that the position of the femoral component in the sagittal plane may affect the kinematics of the knee, as well as patellofemoral mechanics and the balance of flexion-extension. It has been shown that over-flexing the femoral component can alter the relationship of flexion/extension and can affect the range of motion of the knee following surgery^{1,2} and other biomechanical studies have shown that too much flexion could create changes in the quadriceps force requirement and the contact mechanics on the tibiofemoral joint. The present results thus indicate that keeping the femur component in a range of motion that is appropriate for the implant type could promote better function recovery.

Another noteworthy radiographic parameter in this study was the posterior tibial slope. The mean postoperative slope was $6.1^\circ \pm 2.2^\circ$ and 67.5% of patients fell within the preset slope target range. Patients who had a tibial slope within the target range had significantly better HSS scores after surgery than those with more extreme slopes. The effects of P.T.S on the flexion-extension relationship, on the femoral roll back, on the tension of the ligaments and on the range of motion after surgery. In the cruciate-retaining TKA, a more critical role of the appropriate posterior tibial slope may be especially important, as excessive reduction or

increase in the tibial slope can affect knee kinematics^{3,4} and change the function of the posterior cruciate ligament. But the best tibial slope does not always work for all patients due to implant design, native anatomy and ligament status and surgical technique applied.

The combined assessment of sagittal femoral and tibial alignment provided an important finding in this study. Patients who fell within the target range for both parameters had the highest mean HSS at 6 months (90.2 ± 6.1) when compared to the scores of patients with one or both parameters outside the target range (81.1 ± 9.6). This discovery implies that there could be an additive relationship between sagittal alignment parameters and functional recovery. Clinically, the position of both the femoral component and the tibial slope are important factors to consider because they both determine the flexion-extension geometry of the reconstructed knee. However, a change in one parameter could be compensated for or compounded by a change in another parameter, and so an isolated evaluation of one sagittal parameter might not be enough when assessing postoperative knee mechanics.

Sagittal component alignment was also shown to be significantly correlated with patient satisfaction. Overall, 75.8% of patients were satisfied or very satisfied with their outcome at 6 months. Patients who had their femoral component within the target range and had an appropriate tibial slope had higher satisfaction levels. Patients with both sagittal parameters in the target range had the best satisfaction rate. The finding is clinically relevant because there is not always a direct correlation between good radiographic success and satisfaction with the TKA procedure in the patient. Satisfaction may be affected by patient expectations, pain relief, preoperative functional status, rehabilitation, comorbidities, and psychological factors. However, the correlation found in this study indicates that correct sagittal reconstruction may be important in the attainment of the functional goals of TKA patients.

Further support for the sagittal alignment and postoperative function relationship was found in the correlation analysis. The less the femoral component was deviated from the sagittal target, the greater the postoperative HSS, and similar inverse relationship was found for the greater deviation in posterior tibial slope. The results are in line with those of previous studies showing that the relationship between the SCP and the postoperative ROM or functional outcomes is pertinent. There has not been a unanimous consensus in the previous studies, however. Relatively weak and/or absent correlations between individual sagittal radiographic parameters and PROMs have been reported in some studies, indicating that there could be a clinically acceptable range as opposed to a single optimum parameter^{5,6}. These discrepancies could be due to variations in implant design, alignment philosophy, measurement methods, patient characteristics, or variations in outcome assessment.

The present results have implications for surgical planning and execution of primary TKA. Sagittal component positioning should be considered along with coronal alignment and rotational positioning in preoperative templating and during the surgery. The goal should be to restore an appropriate sagittal relationship, while preserving balanced flexion and extension gaps and avoiding excessive alterations of the native knee anatomy. Modern alignment techniques, such as mechanically aligned, kinematically aligned and patient-specific techniques, can generate different sagittal targets and it may be necessary to tailor the target to the patient's anatomy and implant features to create an ideal fit. The results of this study do not set a single universal target but do highlight the need for careful consideration of sagittal alignment.

The following limitations should be kept in mind when interpreting these results: First, the study was performed at a single tertiary care center and involved a relatively small number of patients (120). Second, the length of the follow-up period was short (six months), which did not allow for the determination of whether the associations observed were sustained over time. Third, sagittal alignment was assessed with plain lateral radiographs that can be

impacted by knee flexion, rotation, radiographic technique, and measurement landmarks. Fourth, the study failed to fully evaluate other factors that may influence TKA outcome such as implant design, soft-tissue balance, rehabilitation compliance and patient expectations, and femoral and tibial component rotation and coronal alignment. Last, due to the observational study design, the established relationships can not determine a cause and effect relationship between sagittal component alignment and functional outcome or satisfaction. Long-term, larger, multicenter prospective studies with uniform radiographic protocols and validated patient-reported outcome measures are needed to determine clinically relevant sagittal alignment thresholds after primary TKA.

CONCLUSION

Patient satisfaction and functional outcome after the primary total knee arthroplasty (P-TKA) were significantly related to postoperative sagittal component alignment. Femoral and tibial components that were within the established target ranges had higher 6-month Harris Hip Scores and higher patient satisfaction levels than those that were outside of the target ranges. Increased sagittal alignment of the femoral component and posterior tibial slope (PTS) deviations were correlated with worse functional outcomes, and those within the target range were correlated with the best functional outcomes. A greater deviation from the target range of sagittal alignment of the femoral component and posterior tibial slope (PTS) was correlated with worse functional outcomes; restoration of both sagittal parameters within the target range was correlated with the best functional outcomes. The findings suggest that while maintaining the correct coronal alignment, rotational alignment, soft tissue balancing and rehabilitation are important, sagittal component positioning is equally important during primary TKA. Larger cohort studies with longer follow-up are required to define meaningful and clinically relevant sagittal alignment goals and how they affect patient-reported outcomes over time.

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