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Impact of post-operative hip-knee-ankle angle changes on functional outcome of total knee arthroplasty: a prospective longitudinal study

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ABSTRACT

Background: Coronal malalignment as residual varus may have deleterious effects on functional outcomes of total knee arthroplasty. This study aimed at highlighting the impact of postoperative hip-knee-ankle (HKA) angle changes on the functional outcome of total knee arthroplasty.
Methods: 689 total knee arthroplasty (TKA) knees (from 386 patients) with varus postoperative HKA angle were included. HKA angle was measured on standing orthoscanograms. The knees were divided into 5 subgroups according to postoperative HKA angle as: neutral (0±3.0 degrees); mild (3.1-6.0 degrees); moderate (6.1-10.00 degrees); severe (10.1-5.0 degrees); very severe (>15.0 degrees). Functional outcome of TKA in these subgroups was observed by knee society score (KSS), knee society pain score (KSS-P), Oxford knee score (OKS), lower extremity functional scale (LEFS) at 6 months, 1 year, 2 years, 3 years. Statistical analysis was done by statistical package for social sciences (SPSS) version 16; Spearman's correlation coefficient and Kruskall Wallis test was used to compare the functional outcome of TKA between COHORTs.
Results: 69 knees were present in the mild varus cohort (mean: -1.92), 223 knees in the moderate varus COHORT (mean: -4.77), 260 knees in the moderate varus COHORT (mean: -7.86), 121 knees in the severe varus COHORT (mean: -11.60) and 16 knees in the very severe varus COHORT (mean: -16.54). Mild to moderate varus knees were maximum, but no significant difference in functional outcome between these COHORTs was found by correlation analysis and Kruskall Wallis test.
Conclusions: Changes in postoperative HKA angle (coronal alignment) has no significant impact on functional outcome of TKA.

Keywords: Total knee arthroplasty, Hip-knee-ankle angle, Coronal malalignment, Functional outcome, Mechanical axis

INTRODUCTION

TKA is the best intervention so far for the restoration of desirable knee function in advanced osteoarthritic knees, mostly with Kellgren-Lawrence grade 4 changes. The foremost objective of TKA is a painless, stable, durable and well-functioning joint which closely resembles the anatomical configuration of the knee but not necessarily the exact anatomical joint. Restoration of an overall neutral mechanical axis has been a long term target of TKA, as multiple studies have demonstrated that coronal malalignment, particularly varus, has been associated with higher strain, increased failure rates and poorer outcomes of TKA.[1]

Restoration of a neutral mechanical axis is a dire necessity for the successful outcome of TKA. Coronal malalignment, specially enhanced varus, causes increased

shearing stress on the polyethylene insert, leading to implant failure and higher incidence of revision arthroplasty.[2] A common hypothesis is that postoperative mechanical axis of 0±3 degrees would result in better long-term outcome of TKA, as compared with a group of outliers. But according to Parratte et al 2010 coronal alignment correction did not improve the functional outcome of TKA; which implies that HKA Angle correction only may not be of practical value for predicting functional outcome of TKA.[3]

During progression of knee osteoarthritis, the changes in HKA angle provide a sensitive indicator of deterioration of the knee, due to attrition of bone and cartilage and joint space narrowing, which is very useful in determining the time of TKA.[4] Mechanical alignment or HKA Angle measurements have helped to highlight accelerated joint destruction in arthritic joints with obliquity of the articular surface.[5]

The current gold standard for correct coronal alignment in TKA is an HKA angle of 180±3 degrees, as alignment of components beyond this may be associated with worse functional outcomes of TKA.[6,7] Since the effect of residual coronal malalignment on clinical and functional outcome is contradicting, there is a scope of research whether postoperative mild to moderate varus alignment yields clinical advantages.

The objective of the study was to highlight the effects of postoperative HKA angle changes on the functional outcomes of TKA and to observe the effects of residual varus HKA angle on long-term TKA outcome.

METHODS

We conducted a prospective, observational, longitudinal study, to assess the impact of postoperative HKA angle changes on the functional outcomes of TKA with a follow-up span of 3 years.

The study involved two hospitals, although patient recruitment and the operative intervention with follow-up was carried out at a single tertiary care hospital over a period of 5 and 1/2 years, starting from October 2015 to July 2021. Patient recruitment was done for 4 years (October 2015 to October 2019) and patient follow-up was carried out for 3 years, till July 2021. Institutional ethics committee approval was obtained beforehand and all patients included in the study provided written informed consent after knowing study purpose, risks and benefits.

Patients recruited were in the age group 45-85 years, with severe osteoarthritic varus knees (Kellgren-Lawrence grade 4 osteoarthritic changes), with or without fixed flexion deformity. These patients attended the orthopedics out-patient department (OPD), with knee pain, joint deformities and antalgic waddling gait.

BMI was calculated in kg/m^2 after measuring height with a stadiometer and weight with a digital weighing scale. Following the classification proposed by WHO, patients were categorized into non-obese (BMI <25 or 25-29.9 kg/m^2) and obese (BMI 30.0-34.9, 35.0-39.9 or ≥40 kg/m^2) COHORTs.

Standing long-leg films/orthoscanograms of patients undergoing TKA were used for measuring HKA angle, both preoperatively and postoperatively (Figure 1).

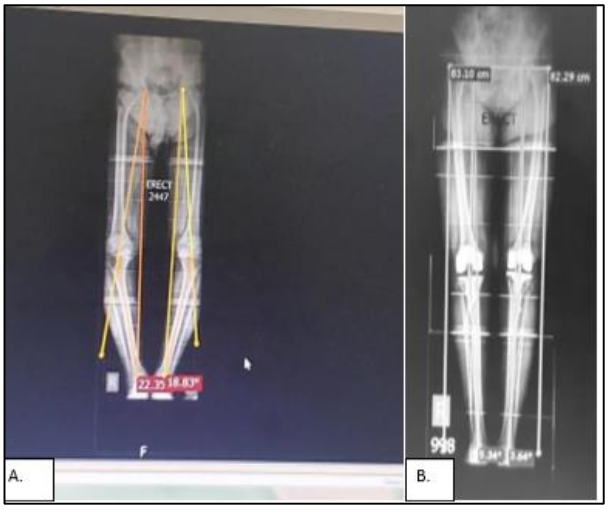

Figure 1: (A) Measurement of the HKA angle from orthoscanograms, preoperatively, in varus knees; (B) standing long-leg films showing postoperative measurement of HKA angle.

The mechanical axis of the femur is defined as a line joining the center of the head of the femur to the intercondylar point between the cruciate ligaments, whereas the mechanical axis of the tibia is defined as a line joining the center of the tibial plateau (interspinous intercruciate midpoint) to the center of the tibial plafond. In a neutrally aligned lower limb, this angle is approximately 0±3 degrees, as the mechanical axes of both the femur and tibia pass through the center of the knee, and coincide with the load bearing axis, which represents the line of ground reaction force passing from ankle to hip.

While taking measurements of the HKA angle with angle tools software, the angle was expressed as an angular deviation from 180 degree, HKA angle is 0 degree in neutral alignment. In varus knees, the center of the knee was lateral to the load-bearing axis, making a varus deviation a negative angle; whereas a medial displacement of the knee center made the valgus angle a positive angle.

But however, in certain situations like enhanced fixed flexion deformity or subluxation of the knee where the center of the knee was distorted, the measurement of the HKA angle may be erroneous, but this error can be compensated by measuring the displacement of the

midspinous point of the tibia, with respect to the intercondylar point of the femur.

A deviation of ±3 degrees in the HKA angle was considered normal. Based on the evaluation of the post-operative HKA angle, TKA knees were divided into several subgroups: 0-3.0 (neutral), 3.1-6.0 (mild varus), 6.1-10 (moderate varus), 10.1-15 (severe varus), HKA angle >15.1 (very severe varus).

Bone mineral density scans by dual energy X-ray absorptiometry (DEXA) of the lower lumbar spine and dual femur were done in patients suspected to have osteopenia or low bone mass; range of motion in the affected knee was measured by goniometer. Pre-anesthetic check-up was done for hypertension, diabetes mellitus, hyperthyroidism, dyslipidemia, ischemic heart disease.

TKA was done under spinal anesthesia with femoral nerve block. All operations were carried out by the same surgical team, using a midline medial para-patellar approach with ligament balancing and gap balancing techniques. Medial release for varus knees, posterior capsular release for fixed flexion deformity were done with patellar resurfacing. Surgery was performed using tourniquet; a standard implant was used (DePuy, PFC Sigma, Johnson and Johnson), which was posterior stabilized, cemented, cruciate sacrificing and fixed bearing type. Antibiotics and low molecular weight heparin/warfarin were administered postoperatively to minimize the risk of infection and thromboembolism. Patients were usually discharged after 5 days for unilateral TKA or 10 days for bilateral TKA, and follow-up was recorded at 6 months, 1 year, 2 and 3 years respectively.

Functional and quality of life outcomes were assessed through KSS, KSS-P, OKS, LEFS. The KSS is a 200-point scoring system, comprising 100 points for a function score (KSFS) and 100 points for a knee score (KSKS). Pain was assessed with KSS-P score, with 50 points; here 0 indicated severe/constant pain, while 50 indicated a painless joint. The original version of OKS had been used here, comprising 12 questions, each scored from 1 to 5, making a maximum total score of 60; here 12 was taken as the best outcome and 60 was the worst. LEFS used was a 20-point scale related to knee function, with 4 points each; a painful knee needing TKA would score 9-10, while a painless knee after TKA would score close to 80 (lower score indicates greater disability). The scoring assessments were done at baseline (pre-operatively) and at all scheduled follow-up visits (post-operatively) by a single rater. All patients undergoing TKA were counseled pre-operatively for pain management and post-operatively for compliance with physiotherapy.

Sampling in the present study was purposive in nature. All patients attending the TKA clinic in the orthopedic outpatient were recruited if they consented to be in the study. The recruitment period was 4 years, while the postoperative follow-up was for 2-3 years. Sample size for the study was calculated based on the proportion of operated knees likely to achieve satisfactory outcome with respect to all anatomical and functional parameters evaluated. Conservatively assuming this to be 50% and an indefinitely large target population, the sample size was estimated to be 600 knees, keeping 4% margin of error and 95% confidence level. Allowing 15% margin for dropouts, the recruitment target was 690 knees. Sample size calculation was done using Raosoft sample size calculator.

Statistical analysis was done using SPSS, version 16, software. Sample characteristics have been summarized as mean and standard deviation (SD), when normally distributed or as median and interquartile range (IQR), when skewed; 95% confidence interval (CI) values have been presented where relevant. Normality of data distribution was assessed by Kolmogorov-Smirnov goodness-of-fit test. As data were not normally distributed, correlation analysis between HKA angle and functional outcome variables of different groups was done by Spearman's rank correlation coefficient. Comparison of functional outcome between different subgroups according to postoperative HKA angle change, was done by Kruskall Wallis test. Cut-off for statistical significance was taken as $p<0.05$.

Ethical considerations

Ethics committee approval document was obtained from the two hospitals before commencement of the study. All patients were informed before participation in the study and a written informed consent document form, pertaining to Indian Council of Medical Research (ICMR) guidelines, was taken from all patients included in the study. The questionnaires used were in form of scoring systems KSS, OKS, KSS-P, LEFS; the patients were explained about the purpose of interview, that their participation was voluntary, they would be informed about the benefits of the study and they could withdraw from the study at any point of time they wanted. They were assured of the confidentiality of data, and all radiological investigations were done in the hospital with their prior consent from hospital Ethics Approval Board.

RESULTS

A total of 391 patients with severe osteoarthritic varus knees (Kellgren Lawrence grade 4) were included in our study, of which 5 were dropouts; thus accounting to 386 patients with 689 TKA knees with varus HKA angle after TKA. The demographic data of TKA knees in the study has been depicted in Table1, which shows the mean age distribution, sex ratio and the BMI status of the patients included. The mean age of patients included was 65.3±6.7, the median or interquartile range (IQR) being 65(9); the mean body mass index was 29.4±4.8, the IQR being 29.0 (6.5).

Figure 2A shows the five subgroups of 689 varus postoperative HKA angle (with mean), through an error

bar diagram; the subgroups being: group1 (69 knees; HKA angle 0-3.0 degrees/neutral), group 2 (223 knees; HKA angle 3.1-6.0/mild varus), group 3 (260 knees; HKA angle 6.1-10.0/moderate varus), group 4 (121 knees; HKA angle 10.1-15.0/severe varus), group 5 (16 knees; HKA angle >15.1/very severe varus). This clearly implies that maximum number of postoperative TKA knees were in moderate varus, followed by mild varus HKA angle.

Table 1: Distribution of TKA knees according to the demographic characteristics and nutritional status of patients (n=689).

Characteristics	N (%)
Age (years)	
<60	138 (20.1)
≥60	551 (79.9)
Sex	
Male	96 (13.9)
Female	593 (86.1)
Nutritional status	
Underweight	02 (0.3)
Normal weight	126 (18.3)
Pre-obesity	258 (37.4)
Obesity class I	224 (32.5)
Obesity class II	60 (8.7)
Obesity class III	19 (2.8)

Figure 2B shows a box plot diagram with average (median) values of postoperative HKA angle in these subgroups of varus TKA knees; group 1 as -1.92, group 2 as -4.77, group 3 as -7.86, group 4 as -11.60, group 5 as -16.54.

Correlation analysis between changes in postoperative varus HKA angle in the 5 subgroups and functional outcome after TKA at 6 months, 1 year, 2 years and 3 years, was observed through Spearman's rank correlation coefficient (rho), but no significant changes were found (Table 2). Association between postoperative varus HKA angle change and functional outcome of TKA by outcome scores KSS, OKS, KSS-P, LEFS, at these specific follow up intervals have been shown in Table 3, but no significant changes on comparison of functional outcome between these subgroups have been observed by Kruskall Wallis test. Significant changes for all these analyses was expected at $p<0.05$. This clearly indicates that there is no significant difference in functional outcome of TKA knees at 3 years between neutral and mild to moderate postoperative HKA angle.

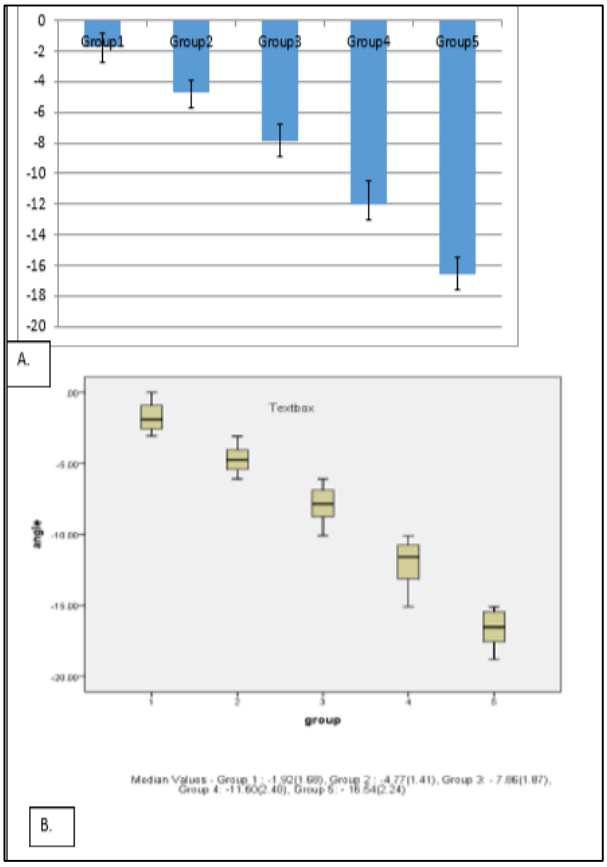

Figure 2: (A) Average (mean±SD) HKA angle of five groups of total 689 varus TKA knees; (B) average (median) values of HKA angle in the 5 groups of TKA knees.

Table 2: Correlation analysis between change in postoperative HKA angle and changes in functional outcome at 6 months, 1 year, 2 years, 3 years of follow-up after TKA.

Functional outcome based on different scores	Correlation at different phases of post operative period			
	At 6 months Rho (p)	At one year Rho (p)	After two years Rho (p)	After three years Rho (p)
Change in KSS	0.015 (0.687)	0.003 (0.931)	0.015 (0.704)	0.057 (0.393)
Change in OKS	0.035 (0.360)	0.034 (0.369)	0.051 (0.184)	0.003 (0.949)
Change in KSSP	0.005 (0.901)	0.005 (0.901)	0.011 (0.769)	0.063 (0.214)
Change in LEFS	0.052 (0.689)	0.036 (0.346)	0.010 (0.792)	0.042 (0.410)

Table 3: Association between change in postoperative HKA angle changes in the 5 subgroups and functional outcome at different follow up phases. Functional outcome scores KSS, OKS, KSSP, LEFS have been assessed for 6 months, 1 year, 2 years, 3 years (Kruskall Wallis test).

Post operative HKA angle	Functional outcome based on							
	KSS							
	At 6 months		At one year		After two years		After three years	
	Median (IQR)	p*	Median (IQR)	p*	Median (IQR)	p*	Median (IQR)	P*
Group 1	42 (23)		61 (30)		78 (40)		85 (48)	
Group 2	35 (23)		54 (28)		68 (36)		73 (38)	
Group 3	39 (26)	0.577	56 (29)	0.674	71 (35)	0.708	79 (38)	0.278
Group 4	36 (24)		54 (30)		70 (37)		71 (34)	
Group 5	30 (24)		45 (31)		56 (41)		66.5 (41)	
	OKS							
Group 1	-28 (3)		-31 (3)		-34 (4)		-35 (5)	
Group 2	-28 (3)		-31 (4)		-34 (3)		-36 (4)	
Group 3	-28 (4)	0.138	-31 (4)	0.513	-35 (3)	0.613	-35 (5)	0.492
Group 4	-28 (4)		-31 (4)		-34 (5)		-34 (4)	
Group 5	-26 (4)		-30.5 (6)		-33.5 (6)		-34 (2)	
	KSSP							
Group 1	35 (20)		35 (20)		35 (20)		35 (20)	
Group 2	35 (20)		35 (20)		35 (20)		35 (20)	
Group 3	35 (20)	0.995	35 (20)	0.997	35 (20)	0.988	35 (20)	0.292
Group 4	35 (15)		35 (15)		35 (15)		30 (15)	
Group 5	35 (20)		35 (20)		35 (20)		20 (19)	
	LEFS							
Group 1	31 (6)		34 (6)		39 (6)		41 (8)	
Group 2	32 (6)		35 (5)		38 (6)		40 (6)	
Group 3	32 (6)	0.847	35 (7)	0.912	38.5 (6)	0.989	40 (7)	0.821
Group 4	31 (8)		35 (7)		38 (6)		39 (7)	
Group 5	30.5 (5)		33.5 (7)		37.5 (7)		38.5 (6)	

Table 4: Comparison of KSS-P values with time (baseline, 6months, 1year, 2years,3years), which show significant changes with time (Friedman's ANOVA; p level significant at p<0.05), till 3 years from baseline, but no significant changes observed after 1 year.

Dunn's Multiple Comparison Test	Difference in rank sum	Significant? P < 0.05?	Summary
KSSP_B vs KSSP_6m	-1006.0	Yes	***
KSSP_B vs KSSP_1y	-1006.0	Yes	***
KSSP_B vs KSSP_2y	-1014.0	Yes	***
KSSP_B vs KSSP_3y	-1014.0	Yes	***
KSSP_6m vs KSSP_1y	0.00000	No	ns
KSSP_6m vs KSSP_2y	-8.0000	No	ns
KSSP_6m vs KSSP_3y	-8.0000	No	ns
KSSP_1y vs KSSP_2y	-8.0000	No	ns
KSSP_1y vs KSSP_3y	-8.0000	No	ns
KSSP 2y vs KSSP 3y	0.00000	No	ns

The KSS is a composite scoring method, with the KSS-P, KS-KS and KS-FS, which indicates improvement in knee pain and knee function with time, but the overall improvement in functional outcome after TKA was the same in all categories of postoperative HKA angle at 6 months, 1 year, 2 years and 3 years respectively. Similarly, OKS is another patient reported outcome measure which reflects the same changes in all subgroups of postoperative HKA angle with same follow-up periods. LEFS reflects the functioning status of the lower extremity; but in this study the difference in postoperative HKA angle has not made any significant changes in functional outcome scores after TKA, as evident from Table 2 and 3.

All functional outcome scores showed steady improvement till 3 years of follow-up, except KSS-P,

which showed significant changes from baseline to 6 months, 1, 2 and3 years of follow-up (p level significant at $p<0.05$); but no significant change was observed after1 year, indicating occurrence of painless stable TKA knees at 1 year itself, as seen by Friedman's ANOVA and Dunn's multiple comparison test (Table 4). But optimum KSS-P scores were not achieved in 234 TKA knees after1 year, even with normal alignment of HKA angle, which indicates that only coronal alignment correction may not create desired functional outcome of TKA.

Overall, it was evident from the present study that there was no difference in functional outcome at 3 years after TKA with different subgroups of postoperative HKA angle change. So, it can be summarized that mechanical axis alignment or only coronal alignment correction after TKA, as manifested by postoperative HKA angle changes, did not have any impact on functional outcomes.

DISCUSSION

The study involved 386 patients undergoing TKA; calculation of BMI of TKA patients was done according to WHO guidelines, 2015.[8] Determination of the mechanical axis of the femur and tibia and the resultant load bearing axis of the lower limb in the present study, was done by accurate measurement of the HKA axis/angle using software (angle tools) on standing orthoscanograms, both preand post operatively.[9-13] Scoring methods used for assessment of functional outcomes of TKA were KSS, KSS-P, OKS and LEFS.[14-16]

HKA angle measurement in 689 varus TKA knees in the present study was done according to the gold standard of measurement of coronal alignment also done in recent studies.[17] Coronal alignment correction or restoration of HKA angle to neutral (0±3 degrees) had been shown to create optimum functional outcome of TKA by most authors.[18] But restoration of mechanical axis only did not produce the desired outcome of TKA in most cases, as had been seen in the present study and also been shown by several other authors.[19] The present study involved 689 TKA knees with postoperative varus HKA angle of varying degrees in different subgroups, but the functional outcome of TKA at 3 years remained almost similar in all cases.

In the present study, correction of HKA angle was done by standard surgical procedure of TKA, but the incidence of painful knee or anterior knee pain was reported in several cases after TKA. The functional outcome of TKA had been assessed by several scoring systems or patient reported outcome measures in this study, which included KSS, OKS, LEFS, which had shown a steady improvement with time, from baseline to 6 months, 1 year, 2 years and 3 years; except the KSS-P. KSS-P score, which showed a consistent improvement at 1 year and was identical at 2-3 years in all painless TKA knees, indicated painless stable knees after TKA. However the present study also showed no improvement in KSS-P in 234 TKA knees, which had been addressed as painful TKA knees even after optimum correction of HKA angle and was also associated with poor functional outcomes of TKA. An insignificant correlation between postoperative HKA angle correction and change in functional outcome scores had been observed in the present study which signified that the correction of coronal alignment only did not provide desired functional outcome of TKA. This observation had been correlated by authors like Parratte et al 2010 who estimated the long-term effect of postoperative mechanical axis alignment on the survival of cemented TKA. The present study also highlighted the fact that mild to moderate postoperative varus HKA angle did not negatively influence the functional outcome of TKA, which had been substantiated by Matzolis et al 2010.[20] But polyethylene insert damage increased with increased degrees of varus alignment of postoperative HKA angle, in posterior stabilized and constrained total knee arthroplasty as observed in the present study and also corroborated with the findings of Meneghini et al 2017 which could be a reason for early failures of primary TKA, requiring revision arthroplasty.[21]

Ligament balancing technique was used in the study instead of computer navigation techniques, but that did not create any impairment of joint line correction even in cases of mild to moderate varus alignment of HKA angle; which had also been proved by Zhang et al 2020.[22]

However, recently published studies had shown no significant difference in malaligned TKA and neutrally restored coronal alignment after TKA which had changed the definition of correct alignment from neutral to ±3 degrees from neutral.[23] Clinical evidence from other studies suggested that medial bone collapse or tibial component failure was associated with varus tibial alignment >3 degrees from neutral. As evident from the present study, postoperative changes in the HKA angle (coronal alignment) do not create any major difference in functional outcomes of TKA, but incidence of anterior knee pain with patello-femoral complications was quite common even after a neutrally aligned TKA. This led to visualizing the aspect of considering the rotational alignment of prosthetic tibio-femoral components after TKA to ensure complete functional outcome after surgery.

The study however had several limitations too, as we could not continue the follow-up till 5 years to assess the impact of unintentional varus alignment on implant longevity. But a precise interpretation of our study is that postoperative mild or moderate varus HKA angle was not associated with serious adverse effects after surgery; so under-correction of postoperative HKA angle to 3-6 degrees may be acceptable for desired functional outcomes of TKA.

CONCLUSION

Postoperative HKA angle changes (coronal alignment restoration) has no impact on functional outcomes of total knee arthroplasty as evident from the present study. So a mild to moderate degrees of postoperative varus HKA angle may not affect the functional outcome of TKA. However, incidence of anterior knee pain, patellar

maltracking, tilting, subluxation with extensor mechanism failure is quite common even after neutral alignment following TKA, for which the determination of rotational alignment of femoro-tibial components after surgery is necessary to ensure the desired functional outcomes of TKA.

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

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