RESEARCH PAPER

A Prospective Radiological Study of Factors Influencing the Distal Femoral Valgus Cut Angle in South Indian Population Undergoing Total Knee Arthroplasty

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ABSTRACT

Background: Achieving a neutral mechanical axis is a cornerstone of successful total knee arthroplasty (TKA). The valgus cut angle (VCA) is used to guide distal femoral resection in TKA, but with accumulating evidence opposing a certain VCA value, this study examined the mean VCA and the anatomical parameters that influence it in an Indian population.

Methods: This prospective observational study included 40 patients (45 limbs) who underwent long-leg weight-bearing radiography. Two blinded observers measured VCA, neck-shaft angle (NSA), medial hip offset (MHO), and hip-knee-ankle (HKA) angle. Data were analyzed using correlation and regression analysis.

Results: The study found a mean VCA of 7.2° ± 1.3°. The correlation coefficient between NSA and VCA was strongly negative, while that between MHO and VCA was slightly positive. Regression study confirmed NSA and MHO as independent predictors of VCA.

Conclusion: VCA varies greatly between individuals and can be strongly influenced by the anatomy of the proximal femur, providing more evidence for tailored surgical planning over the use of predefined angles.

Keywords: Valgus Cut Angle, Total Knee Arthroplasty, Neck-Shaft Angle, Hip Offset, Prospective Study, Coronal Alignment.

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Introduction

The precision with which the knee replacement prostheses are aligned has a substantial impact on the success of total knee arthroplasty (TKA) in treating end-stage knee osteoarthritis [1]. To ensure the long-term survival of a total knee replacement (TKA), it is essential to align the knee joint mechanically (i.e., the HKA is between 177–183°), to preserve natural motion and function [2, 3]. To achieve this goal, surgeons must determine the appropriate distal femoral resection level and the valgus cut angle (VCA).

Orthopaedic surgeons typically use a constant VCA of 5–6° to help them perform TKA, but most of this data was collected in Western countries [4] and does not take into account the variability in human anatomy across ethnicities; therefore, there is some debate about whether a single VCA can be used for all patients [5, 6]. For example, the available data suggest that patients in India may have higher average VCA values than those in the West [7]. Although several previous retrospective studies have indicated the possibility of this [7], to date, no prospective study has been designed to evaluate the difference in VCA values between patients from India compared to other populations. Key questions remain unanswered: What is the true mean and range of the VCA in this population? Which factors — demographic, such as body mass index (BMI) and gender, or morphological, such as neck-shaft angle (NSA) and medial hip offset (MHO) — are its true independent predictors? While retrospective data suggest a role for proximal femoral geometry, a prospective study with standardized, pre-planned measurements is required to establish definitive causal relationships and minimize measurement inaccuracies [8].

This research was therefore designed as a prospective, radiological analysis to accurately determine the VCA and elucidate its influencing factors in Indian patients undergoing TKA. We hypothesized that the VCA would demonstrate significant variability and would be independently influenced by the proximal femoral anatomy, namely the NSA and MHO, rather than by demographic parameters or the preoperative coronal deformity of the knee. The findings aim to provide evidence-based guidance for surgeons, advocating for a move away from fixed-angle strategies towards personalized preoperative planning to improve the precision of TKA in this demographic.

Objectives

- Determine the average Valgus Cut Angle (VCA) and range in TKA patients.
- Examine the effects of radiological and demographic characteristics like age, weight, height, gender, BMI, femoral length, Hip-Knee-Ankle (HKA) angle, Neck-Shaft Angle (NSA), and Medial Hip Offset (MHO) on VCA values.

Materials and Methods

Study Design and Patient Selection: A prospective, observational study was conducted for one year at a single tertiary care orthopaedic centre. The institutional ethics committee approved the study and all participants provided written informed consent.

Initially, the eligibility of 48 patients scheduled for primary TKA for primary osteoarthritis was determined. Inclusion criteria were: (1) age between 50 and 80 years, and (2) patients diagnosed with primary osteoarthritis of the knee requiring TKA. The requirements for exclusion were carefully applied to exclude any confounding anatomical variations. These included: (1) a history of previous femoral or tibial osteotomy or fracture, (2) the presence of ipsilateral hip arthritis or a hip prosthesis, (3) significant extra-articular deformity, (4) inflammatory arthritis, (5) a body mass index (BMI) greater than 40 kg/m², and (6) excessive femoral bending described as a straight line from the piriformis fossa to the top of the intercondylar notch that intersects the medial or lateral femoral shaft cortex.

After applying these criteria, 40 patients (comprising 45 lower limbs) were enrolled in the final analysis.

Radiographic Protocol and Measurements: Preoperatively, all patients underwent a standardized, full-length, weight-bearing anteroposterior radiograph (orthoscanogram) of the entire lower limb. The radiographs were obtained using a standardized protocol: patients stood with both knees in full extension, the patellae facing forward, and feet positioned at 0 degrees of rotation. The X-ray tube was positioned 229 cm from the cassette to minimize parallax error.

A sophisticated digital picture archiving and communication system (PACS) was used to manually take all radiographic measurements on a workstation by two separate senior orthopaedic residents who were unaware of each other's findings or the patient's demographic information. Each lower limb's primary parameters were measured as follows:

- The Valgus Cut Angle (VCA): The angle formed by the mechanical axis of the femur (a line drawn from the center of the femoral head to the center of the knee at the apex of the femoral notch) and the anatomical axis of the femur.
- The Neck-Shaft Angle (NSA): The angle produced between the femoral neck axis and the femoral anatomical axis.
- Medial Hip Offset (MHO): The perpendicular distance between the center of the femoral head and the femoral anatomical axis.
- The Hip-Knee-Ankle (HKA): The angle produced by the mechanical axes of the femur and tibia. An HKA of 180° was considered neutral.
- Femoral Length: The distance between the femoral head and the center of the knee joint.

Patient demographics, such as age, height, weight, and gender were obtained from preoperative anaesthesia assessment charts. Weight in kilograms divided by height in meters squared (kg/m²) yields the Body Mass Index (BMI).

Statistical Analysis: SPSS software version 26.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Descriptive data was demonstrated as mean ± SD for continuous variables and frequencies for categorical variables. The Intraclass Correlation Coefficient (ICC) was employed to evaluate the interobserver reliability of radiography measurements. Pearson's correlation coefficient was used to evaluate the link between the VCA and other continuous variables. An independent samples t-test was employed to compare VCA values between genders. To discover independent predictors of VCA, a multiple linear regression analysis was done, including all factors with a p-value < 0.1 from the univariate study. All tests were declared statistically significant with a p-value less than 0.05.

Results

Of the 48 patients initially assessed, 8 were excluded: three due to a history of previous femoral or tibial fracture, two due to significant femoral bowing, two due to inflammatory arthritis, and one due to a BMI exceeding 40 kg/m². The final cohort comprised 40 patients (45 limbs), including five patients who underwent bilateral TKA. Interobserver reliability for all radiographic measurements was excellent, with ICC values ranging from 0.91 to 0.95.

Demographic and baseline radiographic data for the entire cohort and stratified by gender are presented in Table 1. The mean age was 65.1 ± 7.6 years. Male patients were significantly older than female patients (p < 0.001). Mean BMI was significantly higher in females than males (30.6 ± 4.5 kg/m² vs. 27.3 ± 4.2 kg/m², p < 0.001). Male patients had greater mean height and femoral length (p < 0.001 for both).

Table 1: Radiographic and demographic characteristics of the study population

Parameter	Overall (n=45 limbs)	Male (n=14 limbs)	Female (n=31 limbs)	p-value
Age (years)	65.1 ± 7.6	68.3 ± 6.0	63.7 ± 7.9	<0.001
Height (cm)	155.9 ± 8.7	163.8 ± 6.0	152.5 ± 7.3	<0.001
Weight (kg)	68.8 ± 11.1	71.5 ± 10.3	67.6 ± 11.2	0.002
BMI (kg/m²)	29.6 ± 4.5	27.3 ± 4.2	30.6 ± 4.5	<0.001
Femoral Length (cm)	35.4 ± 2.6	38.0 ± 2.8	34.3 ± 2.0	<0.001
HKA Angle (°)	170.6 ± 5.8	171.4 ± 5.4	170.2 ± 6.0	0.062
Neck-Shaft Angle (°)	120.7 ± 5.7	122.3 ± 5.3	120.1 ± 5.8	0.003
Medial Hip Offset (mm)	46.3 ± 4.3	49.0 ± 4.7	45.2 ± 4.0	<0.001
Valgus Cut Angle (°)	7.1 ± 1.2	6.9 ± 1.3	7.2 ± 1.1	0.028

Data presented as Mean ± Standard Deviation. HKA: Hip-Knee-Ankle; BMI: Body Mass Index.

The mean NSA for the cohort was 120.7° ± 5.7°, with males demonstrating a significantly higher NSA than females (p = 0.003). Mean MHO was 46.3 ± 4.3 mm, significantly greater in males (p < 0.001). The mean HKA angle was 170.6° ± 5.8°, indicating predominant varus alignment, with no significant gender difference (p = 0.062).

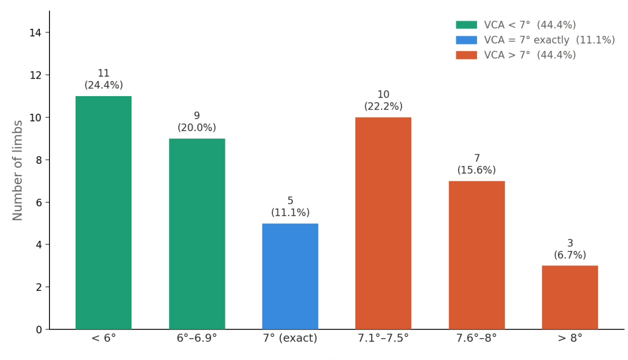
The VCA ranged from 3.8° to 11.2°, with a mean of 7.1° ± 1.2%. The distribution of VCA values is shown in Table 2. Only 31.1% (14/45) of limbs had a VCA of exactly 7°. Notably, 44.4% (20/45) of limbs had a VCA greater than 7.5°, while 24.4% (11/45) had a VCA less than 6°.

Table 2: Distribution of Valgus Cut Angle (VCA) Values

VCA Range	Frequency (n)	Percentage (%)
< 6°	11	24.4%
6° – 6.9°	9	20.0%
7°	5	11.1%
7.1° – 7.5°	10	22.2%
7.6° – 8°	7	15.6%
> 8°	3	6.7%
Total	**45**	**100%**

A small but statistically significant difference in mean VCA was observed between genders (7.2° in females vs. 6.9° in males, p = 0.028).

Figure 1: Distribution of Valgus Cut Angle (VCA) Values



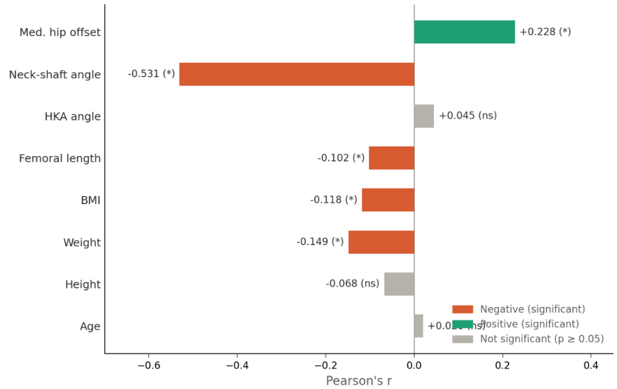
Pearson's correlation analysis between VCA and other parameters is summarized in Table 3.

Table 3: Correlation of Study Parameters with Valgus Cut Angle (VCA)

Parameter	Pearson's r	p-value
Age (years)	0.020	0.641
Height (cm)	-0.068	0.158
Weight (kg)	-0.149	0.003

BMI (kg/m²)	-0.118	0.018
Femoral Length (cm)	-0.102	0.031
HKA Angle (°)	0.045	0.335
Neck-Shaft Angle (°)	-0.531	<0.001
Medial Hip Offset (mm)	0.228	<0.001

Figure 2: Pearson Correlation Coefficients: Study Parameters vs. VCA



A strong negative correlation was observed between NSA and VCA (r = −0.531, p < 0.001). A moderate positive correlation was found between MHO and VCA (r = 0.228, p < 0.001). Weak but statistically significant correlations were noted with weight, BMI, and femoral length, though these were not clinically meaningful. No significant association was found between VCA and age, height, or preoperative HKA angle.

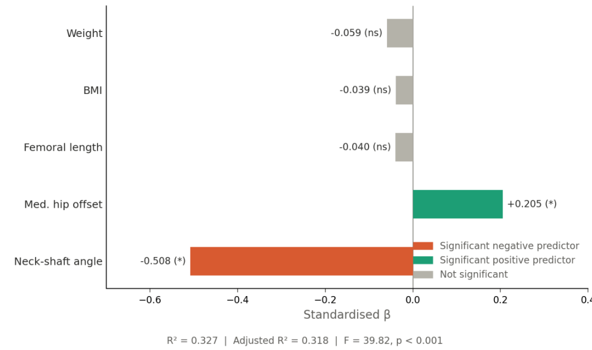
Multiple linear regression analysis was performed to identify independent predictors of VCA, including variables with p < 0.1 from univariate analysis (weight, BMI, femoral length, NSA, MHO). Results are presented in Table 4.

Table 4: Multiple Linear Regression Analysis for Predicting Valgus Cut Angle

Predictor Variable	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (β)	p-value
(Constant)	23.310	1.825	—	<0.001
Neck-Shaft Angle (°)	-0.117	0.009	-0.508	<0.001
Medial Hip Offset (mm)	0.056	0.012	0.205	<0.001
Femoral Length (cm)	-0.019	0.020	-0.040	0.340
BMI (kg/m²)	-0.010	0.011	-0.039	0.372
Weight (kg)	-0.006	0.005	-0.059	0.195

R^2 = 0.327, Adjusted R^2 = 0.318, F-statistic = 39.82, $p < 0.001$

Figure 3: Standardised Regression Coefficients (β) — Independent Predictors of VCA



The regression model was statistically significant ($p < 0.001$) and explained 31.8% of the variance in VCA (Adjusted R^2 = 0.318). NSA was the strongest predictor (β = −0.508), followed by MHO (β = 0.205). No other factors significantly contributed to the model.

Discussion

The principal findings of this prospective study confirm our initial hypothesis: the valgus cut angle in this Indian cohort demonstrates significant variability and is independently determined by proximal femoral morphology, specifically the neck-shaft angle and medial hip offset. The mean VCA of 7.1° ± 1.2° aligns closely with the 7.4° reported by Marya et al. [1] and is notably higher than the 5° to 6° commonly cited in Western populations [2]. The observed range of 3.8° to 11.2° underscores the substantial anatomical diversity within this relatively small cohort, reinforcing that a fixed VCA would lead to alignment outliers in a significant proportion of patients. In our sample, a fixed 7° cut would have been appropriate for only 31.1% of limbs, leaving nearly 70% with potential alignment deviations.

The strong inverse relationship between NSA and VCA is biomechanically consistent and supported by prior studies [3]. A wider NSA (coxa valga) brings the mechanical axis closer to the anatomical axis, reducing the VCA, whereas a narrower NSA (coxa vara) increases divergence and necessitates a larger VCA. Our regression analysis identified NSA as the most influential predictor (β = −0.508), providing robust prospective validation of this geometric principle.

The positive correlation between MHO and VCA, though modest, remained significant in the regression model. This suggests that a more lateralized femoral head center increases the required valgus correction at the distal femur, a finding consistent with studies in Asian populations [4]. While its individual effect was less pronounced than NSA, MHO remains a relevant anatomical consideration in preoperative planning.

A key finding was the absence of a significant correlation between VCA and preoperative coronal deformity (HKA angle). This challenges historical practices that suggested adjusting the VCA based on the degree of varus or valgus deformity [5]. Instead, our data indicate that VCA is an intrinsic property of femoral geometry, independent of wear-induced articular changes. This aligns with Nam et al. [6], who found no significant relationship between the mechanical-anatomical axis angle and overall limb alignment in 493 knees. Clinically, this implies that VCA should be determined from stable proximal femoral anatomy rather than from compensatory adjustments for distal joint deformity.

Demographic factors such as age, height, and gender showed no clinically meaningful influence on VCA. Although a statistically significant gender difference in mean VCA was observed (7.2° in females vs. 6.9° in males), the absolute difference of 0.3° is unlikely to impact surgical precision. These findings are consistent with Deakin et al. [7], who reported no significant effect of gender or height on the femoral mechanical-anatomical angle. Thus, preoperative planning cannot be simplified based on easily accessible demographic data and requires individualized morphological assessment.

Exclusion of limbs with excessive femoral bowing was a deliberate methodological decision to avoid confounding [8]. Femoral bowing can distort VCA calculations and compromise intramedullary guide accuracy [9, 10]. While CT-based planning offers precision, standing long-leg radiographs remain a cost-effective and widely available alternative for identifying extra-articular deformities and calculating VCA [11]. Short knee radiographs are inadequate for this purpose, as they do not visualize the hip center or femoral head-neck relationship [12].

Finally, although debate continues regarding the necessity of achieving neutral mechanical alignment versus kinematic alignment [13, 14], the accuracy of the distal femoral cut remains fundamental. Our findings provide surgeons with evidence to select an individualized VCA regardless of their chosen alignment philosophy, thereby improving the likelihood of achieving intended component positioning.

Conclusion

This study demonstrates significant interindividual variability in the valgus cut angle among Indian patients undergoing TKA. The VCA is independently predicted by proximal femoral anatomy—specifically the neck-shaft angle and medial hip offset—rather than by demographic factors or preoperative coronal knee deformity. These findings argue against the routine use of a fixed valgus cut angle and support individualized preoperative planning using long-leg weight-bearing radiographs to optimize component positioning and patient outcomes.

Originality Statement

This manuscript is original, has not been published previously and is not under consideration for publication elsewhere.

Conflict of Interest

The authors affirm that they have no competing interests or financial relationships that could have influenced the conduct or outcomes of this study.

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