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Posterior Tibial Slope and Metaphysio-Diaphyseal Angle as Radiological Predictors of Knee Osteoarthritis: A Cross-Sectional Study in the Indian Population

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ABSTRACT:

Background: Knee osteoarthritis (OA) is among the most prevalent musculoskeletal disorders globally, disproportionately affecting the Indian population. Posterior tibial slope (PTS) and Metaphysio-diaphyseal angle (MDA) are sagittal-plane radiological parameters that influence tibiofemoral biomechanics and may predispose individuals to, or serve as markers of, osteoarthritic degeneration. However, normative data for these parameters in the Indian population remain incompletely characterised, and their diagnostic utility in OA detection has not been rigorously evaluated.

Objectives: To establish normative values for PTS and MDA in the Indian population; to quantify changes in these parameters associated with radiographic knee osteoarthritis; to evaluate the correlation between PTS and MDA; and to determine the sensitivity and specificity of each parameter as a radiological marker for osteoarthritis detection.

Methods: A descriptive cross-sectional study was conducted at a tertiary orthopaedic centre between September 2023 and March 2024. PTS and MDA were measured on lateral weight-bearing knee radiographs in 121 patients (173 knees): 91 osteoarthritic and 82 radiographically normal. Statistical analyses included independent t-tests, Pearson correlation, linear regression, and ROC curve analysis.

Results: Mean PTS was 9.69° (SD 1.81) in the normal group and 14.05° (SD 2.38) in the osteoarthritic group. Mean MDA was 19.87° (SD 2.70) and 25.03° (SD 3.05) respectively. A moderate positive correlation was identified between PTS and MDA ($r = 0.64$, $p < 0.0001$), with regression equation: PTS = 0.4964 + 0.5060 × MDA. PTS demonstrated sensitivity of 96.7% and specificity of 85.4% as an OA marker; MDA demonstrated sensitivity of 90.1% and specificity of 84.1%.

Conclusion: PTS in the Indian population is higher than values reported in Caucasian cohorts and comparable to those in other Asian populations. Both PTS and MDA increase significantly with knee osteoarthritis and exhibit strong diagnostic performance as

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radiological markers of OA, with PTS demonstrating particularly high sensitivity. These findings have practical implications for risk stratification, pre-operative planning, and population-specific reference standards.

1. INTRODUCTION

Knee osteoarthritis (OA) is a progressive degenerative joint disease of considerable global public health significance, characterised by articular cartilage loss, subchondral bone remodelling, osteophyte formation, and synovial inflammation. It constitutes the leading cause of chronic musculoskeletal disability in older adults worldwide and carries a disproportionate burden in the Indian subcontinent, where demographic, anthropometric, and lifestyle factors — including habitual squatting and floor-level activities — may accelerate the degenerative process [1,2].

The aetiopathogenesis of knee OA is multifactorial, encompassing systemic risk factors such as age, sex, and obesity, as well as local biomechanical determinants that govern load distribution across the tibiofemoral compartments. Among these biomechanical variables, the sagittal geometry of the proximal tibia has attracted increasing research attention. The posterior tibial slope (PTS) — defined as the posterior inclination of the tibial plateau relative to the longitudinal tibial axis on lateral radiography — is a primary determinant of sagittal-plane knee kinematics, ligamentous tension, and tibiofemoral contact mechanics [3-5].

Alterations in PTS influence the anterior translation of the femur on the tibia during weight-bearing and modulate the strain borne by the anterior cruciate ligament, the posterior capsule, and the menisci. A steeper PTS increases anterior tibial shear forces, promotes posterior femoral rollback, and may thereby accelerate chondral wear in the posterior tibiofemoral compartment [11,12]. Conversely, an excessively flat slope may impair flexion and alter the pattern of tibial loading. These biomechanical consequences have generated considerable interest in PTS as both a risk factor and a radiological marker for knee OA.

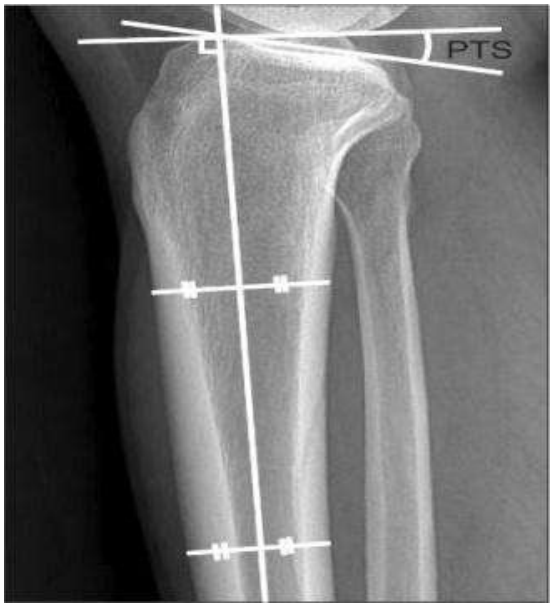

Fig: PTS(Posterior Tibial Slope) Calculation

The Metaphysio-diaphyseal angle (MDA) — the angular relationship between the tibial metaphysis and diaphysis in the sagittal plane — is a related but less extensively studied parameter. Its clinical significance lies in its influence on the mechanical axis in the sagittal plane; an elevated MDA displaces the knee joint centre posteriorly and alters the moment arm of ground reaction forces during gait [3]. The MDA is additionally of direct surgical relevance, informing resection angles in high tibial osteotomy, tibial component placement in total knee arthroplasty, and correction of genu recurvatum deformity.

Normative values for PTS exhibit meaningful inter-ethnic variation. Asian populations consistently demonstrate steeper PTS values relative to Caucasian cohorts, with implications for population-specific prosthetic design, surgical planning, and risk

stratification [6,21]. Population-specific normative data for the Indian subcontinent remain limited, and the diagnostic performance of PTS and MDA as radiological markers of established OA has not been systematically evaluated in this demographic.



Fig: MDA(Metaphysio Diaphyseal angle) calculation

The present cross-sectional study was undertaken to:

(1) establish mean normative values for PTS and MDA in an Indian orthopaedic outpatient population;

(2) quantify and compare these parameters in radiographically normal versus osteoarthritic knees;

(3) characterise the correlation between PTS and MDA; and

(4) determine the sensitivity and specificity of each parameter as a radiological marker for OA detection.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a descriptive cross-sectional study conducted in the Department of Orthopaedics, Government Medical College, Siddipet, Telangana, India, over a ten-month period from September 2023 to June 2024. The study was conducted in accordance with the principles of the Declaration of Helsinki, and written informed consent was obtained from all participants prior to enrolment.

2.2 Participants

A total of 121 patients were enrolled, yielding 173 evaluable lateral knee radiographs. Participants were allocated to one of two groups based on clinical and radiological assessment:

- Osteoarthritic group (n = 91 knees): Patients aged 30 years or above presenting to the orthopaedic outpatient department with knee pain and radiographic evidence of degenerative changes (joint space narrowing, osteophyte formation, subchondral sclerosis), graded using the Kellgren–Lawrence classification.
- Normal group (n = 82 knees): Patients aged 30 years or above attending the orthopaedic department for non-knee complaints, with no clinical or radiological evidence of knee pathology.

2.3 Inclusion and Exclusion Criteria

Inclusion criteria

- All participants were aged 30 years or above and of Indian origin.
- Radiographs were required to be technically adequate for angle measurement.

Exclusion Criteria:

- prior knee fracture or periarticular tibial fracture
- ligamentous knee injury
- severe osteoporosis
- primary or secondary bone tumour
- Charcot neuroarthropathy
- osteolysis of any aetiology
- skeletal immaturity.

2.4 Radiographic Technique and Measurement

Weight-bearing lateral radiographs of the knee were obtained using a standardised protocol. The X-ray tube was positioned with the central beam angled 10 degrees caudally, confirmed with a level inclinometer prior to each exposure [16]. Measurements were performed by two independent trained observers; inter-observer agreement was assessed using the intraclass correlation coefficient (ICC).

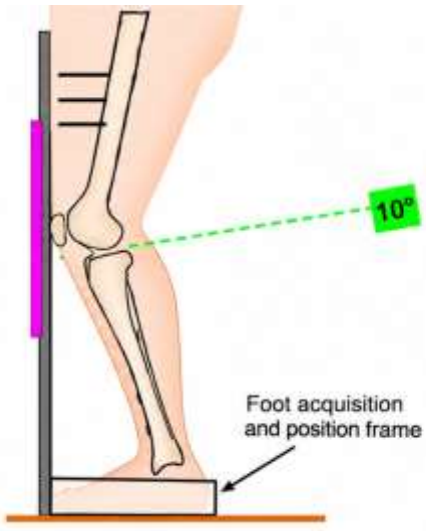

Fig: The right method of taking the X-ray

Posterior Tibial Slope (PTS) was measured as the angle between a line drawn tangent to the posterior tibial plateau and a line perpendicular to the anatomical axis of the tibial diaphysis on the true lateral projection. The Metaphysio-Diaphyseal Angle (MDA) was defined as the angle subtended between the long axis of the tibial diaphysis and the tibial metaphyseal flare. All measurements were performed digitally using workstation software with ±0.1° precision.

2.5 Statistical Analysis

Continuous variables are reported as mean ± standard deviation (SD) with range. Between-group differences in PTS and MDA were assessed using the independent samples t-test; $p < 0.05$ was considered statistically significant. The relationship between PTS and MDA was quantified using Pearson's correlation coefficient (r) and characterised by linear regression analysis. The

diagnostic performance of PTS and MDA in discriminating osteoarthritic from normal knees was evaluated by receiver operating characteristic (ROC) curve analysis, from which sensitivity, specificity, and optimal cut-off values were derived. All analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY).

3. RESULTS

3.1 Patient Demographics

The study cohort comprised 121 patients with a mean age of 56.34 years (range: 38–79 years). The age group most frequently affected by osteoarthritis was 50–60 years. Female patients demonstrated a slightly higher prevalence of OA in this cohort, consistent with the known sex predilection of knee osteoarthritis.

Parameter	Normal Group (n = 82)	OA Group (n = 91)
Mean Age (years)	52.1 ± 8.6	56.3 ± 7.9
Female : Male ratio	1.1 : 1	1.4 : 1
Mean PTS (°)	9.69 ± 1.81	14.05 ± 2.38
Mean MDA (°)	19.87 ± 2.70	25.03 ± 3.05

Table 1: Demographic and radiological characteristics of the study cohort. PTS = posterior tibial slope; MDA = metaphysio-diaphyseal angle; OA = osteoarthritic. Values expressed as mean ± SD.

3.2 Posterior Tibial Slope

The mean PTS in the normal group was 9.69° (range 5–13°; SD 1.81). In the osteoarthritic group, the mean PTS was significantly elevated at 14.05° (range 10–24°; SD 2.38). The between-group difference was statistically significant ($p < 0.0001$). PTS demonstrated a sensitivity of 96.7% and a specificity of 85.4% as a radiological marker for knee OA, representing excellent diagnostic performance.

3.3 Metaphysio-Diaphyseal Angle

The mean MDA in the normal group was 19.87° (range 15–30°; SD 2.70), compared with 25.03° (range 19–34°; SD 3.05) in the osteoarthritic group. This difference was likewise highly significant ($p < 0.0001$). MDA demonstrated a sensitivity of 90.1% and a specificity of 84.1% in discriminating OA from normal knees.

Parameter	Sensitivity (%)	Specificity (%)	p-value
PTS	96.7	85.4	< 0.0001
MDA	90.1	84.1	< 0.0001

Table 2: Diagnostic performance of PTS and MDA in detecting radiographic knee osteoarthritis.

3.4 Correlation and Regression Analysis

Pearson correlation analysis revealed a moderate positive correlation between PTS and MDA across the full cohort ($r = 0.64$, $p < 0.0001$), indicating that these two sagittal parameters vary in a broadly concordant fashion. Linear regression, with MDA as the independent variable and PTS as the dependent variable, yielded the following predictive equation:

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PTS = 0.4964 + (0.5060 × MDA) [R^2 not reported; $p < 0.0001$]

This regression model indicates that for each 1° increment in MDA, PTS increases by approximately 0.51°. The moderate, rather than strong, correlation coefficient (r = 0.64) suggests that while the two parameters share a common biomechanical substrate, they are not entirely interchangeable and may capture partially independent aspects of proximal tibial geometry.

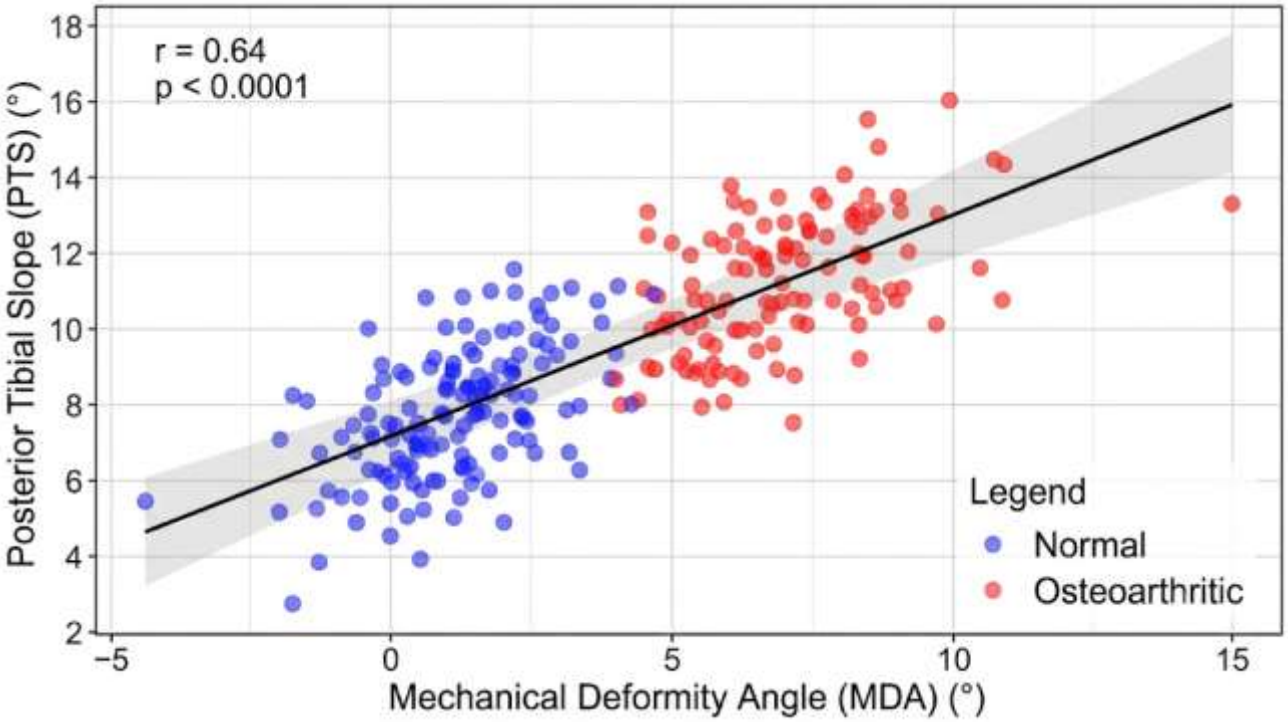

Fig: Scatter plot depicting the linear regression of PTS on MDA across normal and osteoarthritic knees (r = 0.64, p < 0.0001). Normal knees plotted in blue; osteoarthritic knees in red.

4. DISCUSSION

4.1 Normative PTS in the Indian Population: Ethnic Comparison

The mean PTS observed in our normal Indian cohort (9.69°) is consistent with the broader pattern of elevated tibial slope values reported across Asian populations relative to Caucasians. Published normative PTS values for Caucasian subjects typically range from 7° to 9° [35,36], while Asian populations have been reported to exhibit values between 9° and 11° [4,6,21]. Our findings situate the Indian population within the higher end of this Asian range, with values comparable to those reported in Chinese, Malaysian, and Pakistani cohorts [4,6,21]. These ethnic differences likely reflect a combination of genetic, developmental, and habitual loading factors, including the mechanical effects of habitual squatting and floor-level activities prevalent in the Indian subcontinent.

This finding carries immediate practical implications. Tibial component design and resection angles in total knee arthroplasty (TKA) are typically calibrated against Caucasian normative data. Applying such standards to an Indian population risks inadvertently overcorrecting the tibial slope, with attendant consequences for prosthetic kinematics, flexion range, and implant longevity [3,12,22]. Population-specific reference data, as provided by the present study, are therefore of direct surgical relevance.

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4.2 PTS, MDA, and Osteoarthritic Degeneration



Good Unacceptable

Both PTS and MDA were significantly elevated in osteoarthritic knees compared with normal knees in our cohort (14.05° vs. 9.69° for PTS; 25.03° vs. 19.87° for MDA; both $p < 0.0001$). These findings are consonant with the biomechanical hypothesis that a steeper tibial slope increases anterior tibial translation, heightens shear stress at the tibiofemoral interface, and accelerates degenerative cartilage loss [11,19,20,24]. The present cross-sectional design, however, precludes causal inference: it is not possible to determine from the current data whether elevated PTS and MDA precede and contribute to OA development (i.e., function as predisposing risk factors) or whether they reflect adaptive remodelling of the proximal tibial geometry secondary to established degenerative disease. Prospective longitudinal cohort studies, ideally with serial radiographic measurement, are required to resolve this important question.

Fig: Good vs unacceptable radiograph of the knee

The MDA represents the relationship between the tibial metaphysis and diaphysis, and its elevation in OA knees may partly reflect the same adaptive remodelling processes, or alternatively may arise from altered weight-bearing mechanics and periarticular bone remodelling in the context of established degeneration. The moderate inter-parameter correlation ($r = 0.64$) supports a shared biomechanical underpinning whilst confirming that PTS and MDA are not geometrically redundant — they capture related but partially distinct aspects of proximal tibial morphology.

4.3 Diagnostic Performance

A particularly noteworthy finding of the present study is the high diagnostic performance of both parameters in discriminating osteoarthritic from normal knees. PTS achieved a sensitivity of 96.7% and specificity of 85.4%, whilst MDA demonstrated sensitivity of 90.1% and specificity of 84.1%. These values compare favourably with those reported for established OA screening tools and suggest that sagittal tibial angle measurement could serve as a practical adjunct to conventional radiographic grading.

The high sensitivity of PTS is of particular clinical interest: in a population with a high pre-test probability of OA (such as symptomatic patients over 50 years presenting to an orthopaedic outpatient department), a PTS below the threshold value effectively argues against established OA. The more modest specificity reflects the expected overlap in tibial slope distribution between populations, particularly at the lower end of the OA spectrum. Integration of PTS and MDA with clinical data and Kellgren–Lawrence grading could further improve diagnostic precision, and this warrants formal investigation.

4.4 Clinical and Surgical Implications

Beyond diagnostic utility, these findings have direct relevance to surgical planning. In high tibial osteotomy (HTO) for unicompartmental OA, unintentional alteration of PTS is a recognised complication with significant functional consequences; intra-operative awareness of the patient's baseline PTS is therefore essential [3,37]. In TKA, the tibial component slope is routinely set at 3°–7° in most prosthetic systems, irrespective of the native slope; our data suggest that for Indian patients with pre-operative PTS values approaching 14°, such standardised resection angles may represent a marked departure from native

anatomy with unpredictable kinematic consequences [12,22,32,33]. Personalised, anatomy-based tibial resection guided by pre-operative measurement of PTS and MDA merits prospective evaluation in Indian TKA cohorts.

The MDA, by influencing the sagittal-plane mechanical axis, additionally informs the planning of corrective osteotomies for genu recurvatum and the interpretation of full-limb alignment radiographs. Surgeons operating in populations with elevated MDA should account for this parameter when planning both deformity correction and arthroplasty alignment.

4.5 Study Limitations

Several limitations of the current study warrant acknowledgement. The cross-sectional design limits causal inference regarding the directional relationship between tibial geometry and OA development. Kellgren–Lawrence grading of OA severity was employed, but sub-group analysis by OA grade was not performed, and the contribution of OA severity to measured slope values was not isolated. Sample size, whilst adequate for primary outcome analysis, may have limited power for sub-group comparisons by sex and age decade. The study was conducted at a single tertiary centre in Telangana, which may not be fully representative of the broader Indian population. Finally, CT- or MRI-based three-dimensional slope measurement was not available, limiting assessment to the composite tibial plateau slope on lateral projection rather than medial and lateral compartments independently.

5. CONCLUSION

This cross-sectional study demonstrates that both posterior tibial slope (PTS) and Metaphysio-diaphyseal angle (MDA) are significantly elevated in osteoarthritic knees relative to radiographically normal knees in an Indian orthopaedic population. The mean PTS in our normal Indian cohort (9.69°) is higher than values reported in Caucasian populations and consistent with values observed in other Asian groups, reinforcing the need for ethnically specific normative references in orthopaedic surgical planning.

Both parameters demonstrate strong diagnostic performance as radiological markers of knee OA, with PTS achieving particularly high sensitivity (96.7%), making it a clinically useful screening parameter. The moderate inter-parameter correlation ($r = 0.64$) confirms that PTS and MDA are related but non-redundant measures that together provide complementary information on proximal tibial geometry.

These findings support the routine measurement of PTS and MDA in the pre-operative evaluation of Indian patients undergoing knee arthroplasty or osteotomy, and advocate for the development of population-specific tibial slope reference standards to guide implant design and surgical technique. Prospective longitudinal studies are warranted to establish the temporal relationship between tibial slope, OA onset, and progression.

DECLARATIONS

Ethical Approval: The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments. Informed written consent was obtained from all participants.

Competing Interests: The authors declare that they have no competing interests.

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