

The Inverse Morphological Relationship Between Posterior Tibial Slope and Medial Proximal Tibial Angle: A 3D Computed Tomography Study

Oğuzhan Tanoğlu¹, Hakan Cici¹, İlayda İncebiyik², Adem Osmanoglu², Habib Budak²

¹Department of Orthopedics and Traumatology, İzmir Demokrasi University Faculty of Medicine, İzmir, Türkiye

²Clinic of Orthopedics and Traumatology, Buca Seyfi Demirsoy Research and Training Hospital, İzmir, Türkiye

Cite this article as: Tanoğlu O, Cici H, İncebiyik İ, Osmanoglu A, Budak H. The inverse morphological relationship between posterior tibial slope and medial proximal tibial angle: a 3D computed tomography study. *Arch Basic Clin Res.* 2026;8(3):269-272

ORCID IDs of the authors: O.T. 0000-0001-8984-9008, H.C. 0000-0002-9511-4865, İ.İ. 0000-0002-3289-7102, A.O. 0009-0006-2380-744X, H.B. 0009-0005-1882-5697.

ABSTRACT

Objective: The anatomical relationship between the posterior tibial slope (PTS) in the sagittal plane and the medial proximal tibial angle (MPTA) in the coronal plane is of critical importance for preoperative planning. The objective of this study is to investigate the effect of increased tibial slope on MPTA using three-dimensional anatomical models reconstructed from computed tomography.

Methods: A retrospective analysis was conducted on a cohort of 50 healthy adults. The dataset includes parameters such as gender, age, MPTA, and PTS for each adult. The subjects were divided into two cohorts based on their PTS values: those with a slope of 10° or higher were assigned to Group 2 (n=25), while those with 10° or lower were assigned to Group 1 (n=25).

Results: According to the data, MPTA angles in Group 1, which presented lower slope values ranged between 84.8° and 96.2°. In Group 2, which is characterized by higher PTS angles, the PTS angles ranged between 83.4° and 90.1°.

Conclusion: A tendency toward decreased MPTA values is observed when PTS reaches or exceeds 10°. This indicates that higher sagittal slope angles may be morphologically associated with varus alignment in the coronal plane.

Keywords: Deformity, three-dimensional imaging, anatomical models, osteotomy

INTRODUCTION

The successful reconstruction of the lower extremity depends on a comprehensive understanding of the three-dimensional (3D) morphology of the distal femur and proximal tibia.^{1,2} Measured in the coronal plane, the medial proximal tibial angle (MPTA) serves as the primary determinant of varus or valgus alignment and reflects the load distribution.³ In the sagittal plane, the posterior tibial slope (PTS) directly affects the anteroposterior stability and kinematic biomechanics of the knee.⁴ Prior studies have determined the relationship between the increased PTS angles and anterior cruciate ligament (ACL) ruptures.⁵ Increased PTS angles are mentioned as a risk factor for the failure of ACL reconstructions.⁶ Therefore, the authors

suggest slope reduction osteotomies for the failed cases of ACL reconstruction.⁷ MPTA is a widely used anatomical parameter for determining the deformity of the proximal tibia in the coronal plane. Although the measurement method is frequently in two-dimensional (2D), the morphology is virtually 3D, that has components in both coronal and sagittal plane.⁸ Besides, there is an interaction between other anatomical parameters and MPTA, which affects each other.⁹ Recent literature highlights that the PTS exhibits significant inter-individual variability and that an increased PTS can generate adverse shear forces on knee biomechanics.¹⁰ Although classical approaches often consider coronal and sagittal alignment parameters to be independent, it has been established that these two



Corresponding author: Oğuzhan Tanoğlu, E-mail: drtanoglu@gmail.com

Received: September 29, 2026

Revision Requested: October 5, 2026

Accepted: October 7, 2026

Publication Date: October 28, 2026



Copyright© 2026 The Author(s). Published by Galenos Publishing House on behalf of Erzincan Binali Yıldırım University. This is an open access article under the Creative Commons AttributionNonCommercial 4.0 International (CC BY-NC 4.0) License.

planes display simultaneous variations in certain specific phenotypes.¹⁰ Based exclusively on the provided dataset, this study investigates alterations in the MPTA, the primary coronal alignment parameter, when the PTS exceeds the 10° threshold.

MATERIALS AND METHODS

The Institutional Review Board approval for this research was obtained from the Ankara City Hospital Ethics Committee (decision no.: E1/1309/2020, date: 11.11.2020). At the time that ethical approval was obtained, the corresponding author was affiliated with Erzincan Binali Yıldırım University. As there was no active ethics committee for clinical research at the university during that period, the approval was secured from an external institution. Angiographic computed tomography (CT) images of adults older than 18 years of age were reviewed via the hospital registration system. Patients with a history of surgical procedures or fracture fixation of the right lower extremity, prior oncological interventions, any signs of osteoarthritis of the hip, knee, or ankle joints, deformity correction surgeries, or incomplete CT images were excluded from the study. CT images of 78 adults who met the study inclusion criteria were retrieved from radiological records. Given the retrospective design of this study and the use of pre-existing radiological records from the hospital database, obtaining informed patient consent was not required. CT images of adults were imported into Materialise Mimics Innovation Suite version 27 (Materialise, Leuven, Belgium). Only the right tibiae were segmented using the advanced segmentation option with thresholds between 250-2000 Hounsfield unit. The surfaces of the medial and lateral tibial plateaus were scanned (Figure 1), and an anatomical plane was created using the Create primitives option (Figure 2). The total length of the tibia was separated into three parts. The proximal and distal 1/3 borders were scanned, and two spheres were created. The center points of the spheres were merged, and the anatomical axis of the tibia was determined (Figure 3). The medial and lateral tibial plateaus were scanned, and two separate anatomical planes were created. The centers of the planes were merged to form a line used to measure MPTA in the coronal plane. The anatomical landmarks are transferred to Materialise 3-matic 19 (Materialise, Leuven, Belgium). MPTA in adults was measured between the tibial joint line and the tibial anatomical axis in the coronal plane (Figure 4). PTS angles were measured between the proximal tibial plane and the tibial anatomical axis in the

sagittal plane (Figure 5). The study group was divided into two main categories based on mean PTS values. Based on an a priori power analysis conducted using G*Power, a minimum sample size of 21 patients per group was determined. We randomly selected 25 adults with higher PTS angles and 25 adults with lower PTS angles from the cohort. The threshold of the PTS values as 10 degrees was defined according to the results of a 3D anatomical study by Tanoğlu et al.², which investigated the mean PTS angles of healthy adults in Turkish population. The demographic data and the measurement results were analyzed with JASP 95.4 (University of Amsterdam, Amsterdam, Netherlands). The distribution of the data was evaluated using the Shapiro-Wilk test, and the results indicated that the data were normally distributed. Therefore, the Student's t-test was used to compare the results between study groups.

RESULTS

The mean age of Group 1 was 49.8 ± 8.4 , and Group 2 was 47.1 ± 8.5 . We observed no statistically significant difference in mean age between the study groups ($P = 0.268$) (Table 1). Group 1

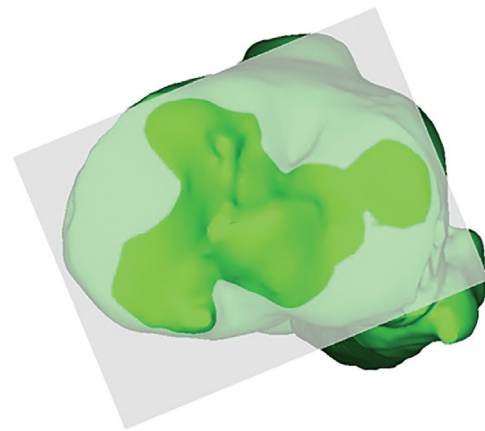


Figure 2. Anatomical plane created according to the scanned medial and lateral plateau.

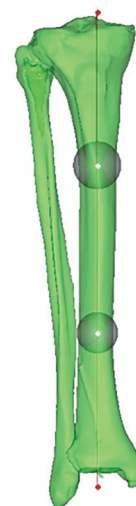


Figure 3. 3D anatomical axis of tibia.
3D, three-dimensional.

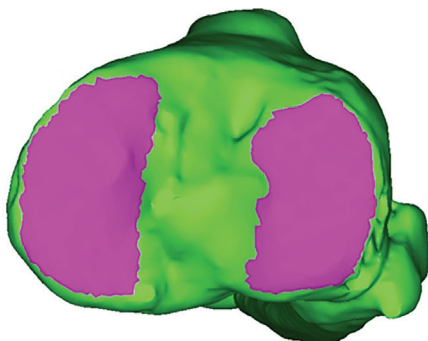


Figure 1. Scanning of medial and lateral plateau.

includes 25 adults with PTS values ranging from 4.1° to 9.3°. Group 2 includes 25 adults with PTS values ranging from 10° to 14.4°. The mean PTS angles were 7.2 ± 1.5 in Group 1 and 11.4 ± 1.4 in Group 2. The mean MPTA was 88.7 ± 3.3 in Group 1 and 86.6 ± 2 in Group 2. The study results revealed a statistically significant difference in mean MPTA values between study groups ($P = 0.011$).

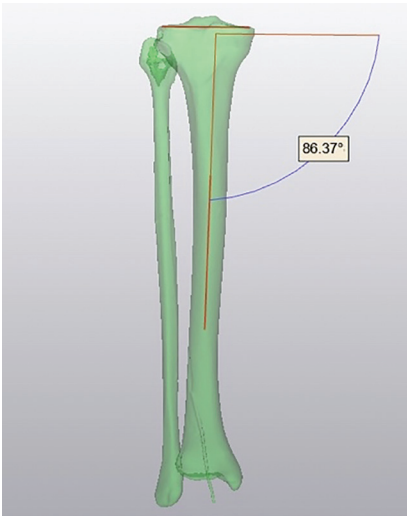


Figure 4. Medial Proximal Tibial Angle measurement in coronal plane.

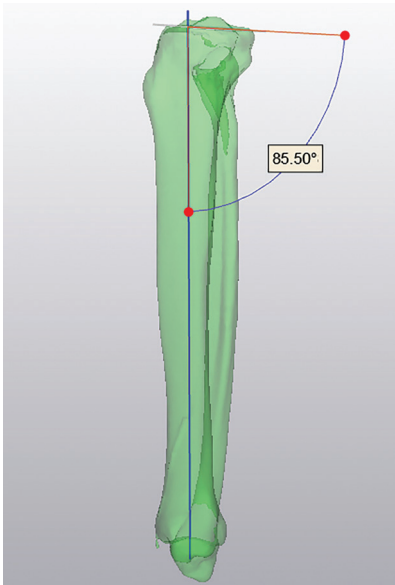


Figure 5. Posterior Tibial Slope measurement in sagittal plane.

DISCUSSION

The primary finding of the present study is an inverse morphological correlation between the PTS and the MPTA. Our data demonstrate that when the PTS reaches or exceeds 10° (Group 2), MPTA values tend to decrease significantly. Conversely, lower PTS values (Group 1) correspond to a higher MPTA. This morphological relationship suggests that an increase in sagittal slope is associated with an adaptation or accompanying deformity profile that tends toward varus alignment in the coronal plane. Biomechanically, the concurrent presence of an elevated PTS and coronal varus malalignment can profoundly disrupt knee kinematics, alter cruciate ligament tension, and exacerbate pathological loading on the medial compartment.^{4,5} Historically, lower extremity alignment studies have frequently evaluated the coronal and sagittal planes as isolated parameters. However, relying on standard 2D radiography often leads to measurement inaccuracies due to rotational variations.¹¹ Use of advanced 3D anatomical models reconstructed from CT scans ensures exceptional measurement accuracy compared to standard 2D radiographs. 3D reconstruction programs allow for precise, reproducible anatomical measurements of bone structures that 2D imaging often misrepresents due to rotational variances.¹¹

These biomechanical and morphological findings hold substantial clinical relevance, particularly in the surgical management of knee deformities. Genu varum, primarily driven by the proximal tibia, is the most prevalent deformity detected in severe knee arthrosis.¹² In younger adults, opening wedge high tibial osteotomy is frequently employed as a joint-preserving procedure to shift abnormal mechanical loads from the medial plateau to the lateral compartment.³ Furthermore, an increased PTS angle is a well-established risk factor for both primary ACL ruptures and subsequent graft failures.⁵⁻⁷ Slope-reducing osteotomies, which are frequently performed in this patient population, serve to protect the graft by decreasing the mechanical load applied to the ACL.^{6,7,13}

Our study results validate that preoperative planning for single-plane correction of the deformity is insufficient, and 3D biplanar planning is crucial to uncovering the intricate relationship between these anatomical parameters. Consequently, in the preoperative planning of corrective osteotomies, it is imperative to address not only varus malalignment but also excessive PTS. This correlation underscores that the existing MPTA should be considered in preoperative planning for slope-reducing surgery.

Table 1. Comparison of the Study Groups

	Group 1		Group 2		P value
	Mean	SD	Mean	SD	
Age	49.8	8.4	47.1	8.4	0.26
MPTA	88.7	3.3	86.6	2	0.011*
PTS	7.2	1.5	11.4	1.4	<0.001*

*Statistically significant. SD, standard deviation; MPTA, medial proximal tibial angle; PTS, proximal tibial slope.

Study Limitations

This study has some limitations. First, the retrospective design and the relatively small sample size (50 adults) may limit the generalizability of the findings. Furthermore, the cohort consisted entirely of healthy individuals. Consequently, the effect of degenerative morphological changes on this multiplanar relationship remains unclear. Future research should prioritize conducting a comparative 3D-CT study to evaluate these lower-limb anatomical parameters in healthy adult cohorts and in patients with advanced knee osteoarthritis, to determine how the PTS-MPTA relationship behaves in the presence of joint degeneration.

CONCLUSION

Our results validate that traditional single-plane preoperative planning is insufficient for managing complex proximal tibial deformities. The intricate morphological relationship between the sagittal and coronal planes mandates comprehensive 3D biplanar evaluation. When performing planned corrective osteotomies—whether addressing medial compartment osteoarthritis or offloading an ACL reconstruction—surgeons must avoid evaluating these parameters in isolation. It is imperative to meticulously account for both varus malalignment and excessive PTS to ensure optimal surgical outcomes and to restore physiological knee kinematics.

Ethics

Ethics Committee Approval: The Institutional Review Board approval for this research was obtained from the Ankara City Hospital Ethics Committee (decision no.: E1/1309/2020, date: 11.11.2020).

Informed Consent: Due to the retrospective design of this study, obtaining informed consent from the patients was not required; permission was obtained from the hospital administration to use the radiological records from the hospital database for the study.

Footnotes

Author Contributions

Concept Design – O.T.; Data Collection or Processing – İ.İ., A.O., H.B.; Analysis or Interpretation – O.T., H.C.; Literature Review – İ.İ., A.O., H.B.; Writing, Reviewing and Editing – O.T., H.C.

Declaration of Interests: The authors declare no conflict of interest.

Funding: The authors declare no financial support or funding.

REFERENCES

1. Hohlmann B, Asseln M, Xu J, Radermacher K. Investigation of morphotypes of the knee using cluster analysis. *Knee*. 2022;35:157–163. [\[CrossRef\]](#)
2. Tanoğlu O, Subaşı İÖ, Gökğöz MB, Arıcan G. Is proximal tibia sufficient for accurate measurement of tibial slope angles on three-dimensional tomography-based anatomical models? *Curr Med Imaging*. 2021;17(12):1419–1424. [\[CrossRef\]](#)
3. Arora G, Parvir K, Chinta ST, Jolly A, Patel JH. Restoration of limb alignment in post-traumatic genu varum case using medial open wedge proximal tibial osteotomy with posterior tibial slope correction: a case report. *J Orthop Case Rep*. 2026;16(6):407–413. [\[CrossRef\]](#)
4. Karimi E, Norouzi M, Birjandinejad A, Zandi R, Makhmalbaf H. Measurement of posterior tibial slope using magnetic resonance imaging. *Arch Bone Jt Surg*. 2017;5(6):435–439. [\[CrossRef\]](#)
5. de Boer JJ, Blankevoort L, Kingma I, Vorster W. *In vitro* study of inter-individual variation in posterior slope in the knee joint. *Clin Biomech (Bristol, Avon)*. 2009;24(6):488–492. [\[CrossRef\]](#)
6. Liu Z, Jiang J, Yi Q, et al. An increased posterior tibial slope is associated with a higher risk of graft failure following ACL reconstruction: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(7):2377–2387. [\[CrossRef\]](#)
7. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):2846–2852. [\[CrossRef\]](#)
8. Hiyama S, Rao RP, Takahashi T, Palan J, Pandit H. Biplanar radiographic analysis of knee alignment: a stepwise approach for phenotype classification and knee arthroplasty planning. *EFORT Open Rev*. 2025;10(10):745–755. [\[CrossRef\]](#)
9. Wen L, Yu Y, Ma D, Wang Z. Effect of joint line orientation parameters on initial bone resection in mechanically aligned total knee arthroplasty: a retrospective clinicoradiological correlation study. *BMC Musculoskelet Disord*. 2023;24(1):222. [\[CrossRef\]](#)
10. Hirschmann MT, Moser LB, Amsler F, Behrend H, Leclercq V, Hess S. Phenotyping the knee in young non-osteoarthritic knees shows a wide distribution of femoral and tibial coronal alignment. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(5):1385–1393. [\[CrossRef\]](#)
11. Naendrup JH, Drouven SF, Shaikh HS, et al. High variability of tibial slope measurement methods in daily clinical practice: comparisons between measurements on lateral radiograph, magnetic resonance imaging, and computed tomography. *Knee*. 2020;27(3):923–929. [\[CrossRef\]](#)
12. Bellemans J, Colyn W, Vandenuecker H, Victor J. The Chitranjan Ranawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus. *Clin Orthop Relat Res*. 2012;470(1):45–53. [\[CrossRef\]](#)
13. Kayaalp ME, Inoue J, Konstantinou E, Kahraman HÇ, Erden T, Musahl V. Radiographic medial posterior tibial slope $\geq 16^\circ$ predicts multiple revisions after anterior cruciate ligament reconstruction. *J Exp Orthop*. 2026;13(1):e70624. [\[CrossRef\]](#)