

Correlation Between Tibial Cortical Thickness and Volumetric Bone Mineral Density to Inform Cementless Total Knee Arthroplasty Implantation

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INTRODUCTION: Cementless total knee arthroplasty (TKA) has gained exponential interest due to modern porous implants promising durable fixation, reduced operative time, and simplified revisions, yet early aseptic loosening of tibial components persists as a common postoperative complication. [1,2] We previously demonstrated that volumetric bone-mineral density (vBMD) derived from computed tomography (CT) can be useful to identify patients with appropriate bone strength for cementless TKA.[3] Compared to plain radiographs, however, CT-scans have increased cost and decreased availability.[4,5] While prior studies suggest that cortical thickness can predict central or peripheral bone quality,[6,7] the relationship between cortical thickness measurements and bone density at the proximal tibia has not been established. No study has rigorously quantified this correlation specifically within the planned tibial resection zone in TKA. This study aimed to establish the correlation between tibial cortical-thickness measured in standard radiographs and vBMD under the implant, measured from preoperative CT-scans. We hypothesized that thicker tibial cortices would correlate with higher vBMD.

METHODS: We conducted a single-center, retrospective cohort analysis of 82 consecutive adult patients (36 female and 46 male, ages 50 - 86) undergoing robotic-assisted primary TKA (MAKO, Stryker) between 15 January 2017 and 1 December 2024. All patients received a preoperative CT scan with a BMD reference phantom (Mindways Software) and weight-bearing anteroposterior (AP) and lateral tibial radiographs within three months preoperatively. Exclusion criteria included hardware on ipsilateral or contralateral knee surgery, major tibial deformity, revision cases, incomplete imaging datasets, and known metabolic bone disorders. Tibial cortical thickness measurements were performed digitally (PACS) at 10 cm and 15 cm distal to the tibial spines on both AP and lateral views by two observers. Cortical thickness ratios were calculated as (medial + lateral cortex thickness)/outer cortical diameter. Cross-sectional trapezoidal area was calculated using the average of the cortical thickness multiplied by the distance between the measurements, (Cortical thickness at 10cm + Cortical thickness at 15cm)/2*10cm, on AP and lateral radiographs. vBMD was quantified at the anterior-medial, posterior-medial, posterior-lateral, and anterior-lateral quadrants of the planned tibial cut. The trapezoidal area (cm²) was correlated with quadrant-specific vBMD. The primary outcome was to assess the relationship between cortical thickness ratios and vBMD. Secondary analyses stratified patients into cortical thickness categories (High, Intermediate, Low). Reliability of radiographic measurements was confirmed via intra- and inter-rater intraclass correlation coefficients (ICC).

RESULTS: Mean vBMD was highest in the posterior-medial quadrant (255 ± 73 mg/cm³) and lowest in the anterior-lateral quadrant (152 ± 59 mg/cm³). Radiographic cortical-thickness ratios measured at 15 cm distal to the tibial spines on lateral radiographs demonstrated the strongest correlation with vBMD (Spearman r = 0.40, 95% CI: 0.20–0.57). Measurements taken 10 cm distal on lateral radiographs (r = 0.26, 95% CI: 0.05–0.46) and AP views at 10 cm (r = 0.22, 95% CI: 0.00–0.42) showed weaker correlations. The cortical ratio at 15 cm on AP radiographs did not correlate with BMD (r = 0.21, 95% CI: -0.01–0.41). Trapezoidal area measurements of the medial tibia on AP radiographs displayed a moderate correlation with vBMD (r = 0.63, 95% CI: 0.47–0.75). Intra- and inter-rater reliability for cortical-thickness measurements were excellent (ICC > 0.80 for all measurement points).

DISCUSSION: Radiographic cortical-thickness, particularly at 15 cm distal to the tibial spines on lateral radiographs, correlates moderately with CT-derived BMD beneath the tibial resection, highlighting their potential as reproducible preoperative screening tools for cementless TKA candidates. Medial tibial trapezoidal area on AP radiographs demonstrated a moderate correlation, offering an additional predictor for BMD. Although radiographic metrics cannot fully replace CT-based BMD assessments, these findings support their integration into future clinical practice to inform implant selection, potentially reducing the incidence of early aseptic loosening associated with cementless tibial fixation and increasing operative efficiency.

SIGNIFICANCE/CLINICAL RELEVANCE: This study is the first to establish quantitative correlations between routine radiographic cortical thickness measurements and vBMD, demonstrating that cortical thickness at 15 cm distal to tibial spines provides a promising preoperative screening tool for cementless TKA candidate selection. These findings support the integration of standard radiographic metrics into clinical practice to potentially reduce early aseptic loosening without requiring costly CT-based BMD assessments.

References: [1] Mosher J Arthroplasty 2024; [2] Nam, J Bone Joint Surg 2019; [3] Borsinger, J Arthroplasty 2024; [4] Suh, Clin Orthop Surg 2024; [5] Choi, Medicina 2022; [6] Sadat-Ali, Int J Appl Basic Med Res 2015; [7] Patterson, J Bone Joint Surg 2025

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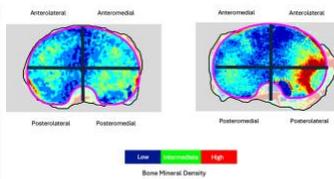


Fig. 1 – Regional BMD distribution beneath the tibial resection



Fig. 2 – Radiographic measurement technique for cortical thickness assessment and trapezoidal area analysis

Quadrant	View	Area of a Trapezoid	Spearman r	Lower 95% CI	Upper 95% CI
Anterior-Medial Quadrant	AP Medial	0.41	0.21	0.28	
	AP Lateral	0.15	-0.07	0.36	
	Lateral Anterior	0.22	0	0.42	
Anterior-Lateral Quadrant	Lateral Posterior	0.02	-0.2	0.24	
	AP Medial	0.05	-0.17	0.27	
	AP Lateral	0.09	-0.13	0.31	
Posterior-Lateral Quadrant	Lateral Anterior	0.24	0.05	0.46	
	Lateral Posterior	0.24	0.02	0.44	
	AP Medial	0.07	-0.15	0.28	
Posterior-Medial Quadrant	AP Lateral	0.13	-0.1	0.34	
	Lateral Anterior	0.37	0.14	0.54	
	Lateral Posterior	0.48	0.3	0.64	
Anterior-Medial Quadrant	AP Medial	0.43	0.47	0.75	
	AP Lateral	0.25	0.05	0.45	
	Lateral Posterior	0.41	0.23	0.58	
Anterior-Lateral Quadrant	Lateral Anterior	0.25	0.03	0.45	
	Lateral Posterior	0.25	0.03	0.45	

Fig. 3 – Correlations between volumetric BMD and radiographic measurements varied by anatomical quadrant