Predicting Preoperative Knee Bone Strength to Prevent Early Failure in Cementless Total Knee Arthroplasty

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INTRODUCTION: With the increasing utilization of newer-generation cementless total knee arthroplasty (TKA), the preoperative prediction of bone quality has emerged as a significant concern. This arises due to the observed poor bone ingrowth and initial instability following cementless TKA, particularly in patients with low bone density. Central bone mineral density (BMD), a conventional metric assessed at the spine and hip, does not correlate with the actual bone strength of the femur, where the prosthesis is affixed. Recognizing such limitations, attention has turned to Hounsfield units (HU), a measure of the standardized linear attenuation coefficient on Computed tomography (CT) imaging, known for its ability to estimate BMD specifically around the knee joint. Consequently, this study aims to investigate the correlation between preoperative HU of the distal femur and the corresponding real bone strength.

METHODS: In this prospective study, 190 knees that underwent standard posterior stabilized cementless TKA between May 2022 and May 2023 were included. HU of the distal femur was assessed using the CT scan taken just before the surgery, and the corresponding bone fragment was obtained during surgery and measured for its bone strength using an indentation test. We conducted: 1) analysis on the relationships between HU and the 1st failure load (FL) of actual bone, and 2) the establishment of a cementless TKA screening model utilizing the minimal required strength (MRS) and estimated failure load (EFL), suggesting guidelines from the perspective of HU values.

RESULTS:

In the linear regression analysis, HU showed a significant correlation with the 1st FL. Among the HU measurements in three planes, the coronal HU exhibited the highest correlation with the failure load (R2=0.446, 0.279, 0.270 in coronal, sagittal, and axial planes, respectively). Upon the cementless TKA screening model, 103 cases (54%) were suitable for cementless TKA (MRS < EFL), while 87 cases (46%) for cemented TKA (MRS > EFL). Coronal HU was the most suitable measurement method for implementing this model, with a minimal cut-off value of 72 points for selecting cementless TKA.

Table 2. Correlation test and Linear regression analysis of HU and 1st failure load according to the plane

Correlation Test			Linear regression analysis		
Plane	Pearson Correlation (r)	*p-value*	*β (95% C.I.)*	R^2	*Significance*
Coronal HU	.668	< 0.001	.624 (4.89, 21.78)	.446	< 0.001
Sagittal HU	.528	< 0.001	.403 (25.54, 40.85)	.279	< 0.001
Axial HU	.520	< 0.001	.397 (9.91, .30.67)	.270	< 0.001

Table 3 Comparisons of characteristics between the identified groups by the prediction model

	Cementless: MRS < EFL	Cemented: MRS > EFL	*p-value*
n	103	87	
MRS, N	1672.4 ± 243.9	1607.0 ± 233.4	.061
1st failure load, N	84.1 ± 35.4	30.3 ± 11.5	< 0.001
EFL, N	2932.7 ± 1389.4	1006.6 ± 381.8	< 0.001
Age, years	68.4 ± 5.4	67.7 ± 5.3	.350
BMI, kg/m^2	27.4 ± 3.5	26.9 ± 3.3	.314

Table 4 AUCs and HU Cut-off values in choosing cementless TKA by the planes

	AUC	*p-value*	Cut-off value
Coronal HU	.823	< 0.001	72
Sagittal HU	.792	< 0.001	59
Axial HU	.810	< 0.001	95

DISCUSSION AND CONCLUSION: The utilization of the coronal HU can be a crucial predictor of actual bone strength. Upon applying the cementless TKA screening model, consideration for cementless TKA is warranted when the coronal HU is 72 or higher.