Speculation for Failure Load of the Knee using Central Bone Mineral Density for Preventing Early Failure after Cementless Total Knee Arthroplasty

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INTRODUCTION:

Recent 3D printing technology improves porous surface structure that enhance biological fixation of cementless total knee arthroplasty (TKA). Adequate bone quality is prerequisite for bone ingrowth and resisting subsidence, therefore, it is essential for preventing early failure after cementless TKA. However, despite remarkable technological innovation, the definition for optimal bone quality for cementless TKA and the gold standard method to estimate bone strength before cementless TKA have not been established yet. Previous studies reported that Hounsfield unit (HU) of preoperative knee CT is well correlated with central bone mineral density (BMD) that assessed by Dual Energy X-ray Absorptiometry (DEXA) and it is useful for estimation of bone quality before TKA. In addition, recent study demonstrated the real bone failure load correlated preoperative HU. This study was performed to demonstrate an arithmetic equation regarding the relationship between failure load of real bone of knee and preoperatively assessed central DEXA.

METHODS:

One-hundred-seven patients were prospectively enrolled and received a single, current standard PS TKA. Resected bones that generated after box preparation were obtained. Preoperatively, central DEXA (femur neck and L2) and knee CT were taken in all patients. HUs of the resected bone area were read by two orthopaedic surgeons. All resected bones were kept frozen immediate after TKA until laboratory test. Indentation tests using 6mm flat punch were performed at the same area of resected bones and stiffness, 1st failure load, and maximal failure load were calculated. Correlation analyses and multivariate linear regression analyses were performed between central DXA and preoperative HU. In addition, linear regression analyses between real bone strength and preoperative HU were performed.

RESULTS:

DXA BMD of L2 and femur neck were strongly correlated with preoperative HU at their own region (all $r > 0.5$, all $p < 0.01$). Multivariate linear regression analyses revealed preop knee HU well correlated with DXA of femur neck and L2 spine (R2=0.409, p<0.01). The failure loads of resected bones were significantly correlated with HU of preoperative knee CT (r=0.640; p<0.001). Linear regression analysis revealed correlation between failure load and HU (β=0.640, R2=0.404, p<0.001). As the contact surface area of punch which was used in this test was 28 mm^2, the failure load based on preoperative HU according to each femoral size can be calculated. Finally, using this equation, we can substitute HU with central DXA and speculate real bone failure load based on central DEXA.

For practical example,

Failure load is 30.895 + 0.321 x (HU) according to linear regression analysis.

Real bone failure load would be [30.895 + 0.321 x (HU)] x area ratio.

Area ratio is shown on table (1).

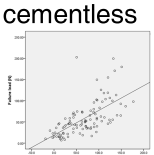
If patient body weight is 70 kg, then knee joint should stand 1400 to 2100 N for minimal Active daily living.

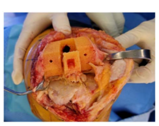
If the preoperative HU is 66 and number 1 femur size templated, the estimated failure load would be 1322.9 N [(30.895 + 0.321 x 66) x 25.4] and it is smaller than minimal required load.

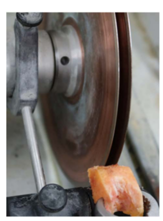
So cementless TKA is not recommended on this patient.

DISCUSSION AND CONCLUSION:

We demonstrate the relationship between preoperative central BMD and failure load of real resected bone at knee. Using this equation, we can speculate real bone failure load of knee based on central BMD in patients who are scheduled for cementless TKA.







Size	AP (mm)	ML (mm)	Area (mm^2) x2	Area ratio to 6mm punch
#1	16.8	21.4	719	25.4
#2	18.1	22.9	829	29.3
#3	19.3	24.4	942	33.3
#4	19.3	25.9	998	35.3
#5	20.2	27.4	1107	39.1
#6	22.3	28.9	1289	45.5