Predicting Suitable Bone Strength for Cementless TKA Using Novel Visual Grading System and CT-Based Hounsfield Unit

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INTRODUCTION: The increasing prevalence of cementless total knee arthroplasty (TKA), now accounting for 18% of TKA utilization in the US, signifies a shift in patient demographics and surgical preferences. While advancements in implant design and material manufacturing have addressed some of the initial fixation challenges faced by earlier generations of cementless implants, concerns about migration of component or early aseptic loosening persist. However, as no gold standard for determining adequate bone quality specific to cementless TKA nor for assessing method to evaluate bone quality of the knee have been established, surgeons face a significant challenge to select optimal bone quality before cementless TKA. This study was conducted to investigate (1) the relationship between intraoperative visual grading system for osteoporosis screening of the knee and the actual bone strength at the knee that measured by indentation test; (2) the relationship between Hounsfield unit (HU) of conventional CT before cementless TKA and intraoperative visual grading system; and (3) the diagnostic value of HU for osteoporosis screening of the knee.

METHODS: We chose to investigate 131 knees undergoing standard posterior stabilized (PS) prosthesis TKA (Triathlon, Stryker, NJ, USA) between November 2021 and March 2023. We included only patients with primary osteoarthritis who underwent TKA and who agreed to participate. Medical records and radiological results were reviewed. Conventional-based HU of coronal image corresponding to box that reproduced during box preparation was assessed 1 week prior to TKA. The average HU was 77.7 (range, -19.1 – 177.0). After femur and tibia bone resection, irrigation with pulsatile lavage was done and all knee were classified into 4 grades based on visible porosity and cutting surface contour maintenance; excellent (no pore), good (rare pore<2mm), fair (frequent pore>2mm but maintained cutting surface contour) and poor (widespread pore>2mm and destroyed cutting surface contour).(Fig1) With linear precision saw, 2 parallel diamond blades (gap 6mm) were set to make parallel bone cut to prep bone specimen for indentation test. The bone specimen was made 6mm in thickness and then placed on the servohydraulic machine for indentation test machine, which used 6mm diameter flat punch indenter with area of approximately 28.3mm2. (Fig2). The indentation depth and load values were recorded at 30Hz, and the results were analyzed. Estimated withstanding strength (EWS) was calculated based on failure load of bone fragment and area of femur component. Minimum required strength (MRS) was calculated by 2.5 times patients' body weight. Ideal cementless TKA candidate was defined as patient whose EWS was larger than MRS. Correlations between vBMD and the failure load of actual bone strength at the knee were analyzed.

RESULTS:

Although actual bone strength of poor group was not different from fair group, those of fair, good and excellent group were significantly different. (Fig4) In addition, HU was strongly correlated to visual grading system and HU of each grade showed significant difference. (Fig5) Finally, correlation analysis indicated a strong correlation between HU and the actual bone strength of the knee (correlation coefficient=0.719, $p<0.01$) and linear regression analysis showed a moderate correlation (($R^2 = 0.51$, $p<0.01$). ROC curve showed an excellent AUC value (0.984) with 91.9% of sensitivity and 92% of specificity. The cut-off value of HU for cementless TKA candidate is 58.82.

DISCUSSION AND CONCLUSION:

Our novel visual grading system for osteoporosis screening of the knee is strongly correlated with CT-based HU. Our novel visual grading system and conventional CT provides accurate information on proper bone condition for cementless TKA.