

Aging effect on femoral stress fracture risk after computer-navigated total knee arthroplasty

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Introduction: Recent clinical studies have shown that computer navigation for total knee arthroplasty (TKA) provides improved component alignment accuracy, and can help to avoid femoral malrotation and errors in axial alignment [1]. However, femoral stress fracture after computer-navigated TKA has been reported due to the pin hole [2]. We hypothesized that osteoporosis would be one of the key factors in pin hole fracture after computer-navigated TKA. In this study, we investigated the stress around the femoral pin-hole for different elastic moduli and ultimate stresses and different pin penetration modes to understand the aging effect on femoral stress fracture risk after computer-navigated TKA.

Materials & Methods: A three-dimensional finite element model of a male femur was reconstructed from 1 mm thick computed tomography (CT) images using FEMAP® (EDS Corp., USA) (Figure). The CT images were taken from a healthy human body whose height and age were 175cm and 21 years. The femur models included cortical bone, cancellous bone, and canal and the material properties of bony models were obtained from previous literature. Two pin holes cases of 3 mm and 4 mm diameters of were modeled. The distances of the two pin-holes from the distal end were 70 mm and 100 mm. Then, four pin penetration modes, unicortical, bicortical, half-bicortical, and transcortical in tubular bone were developed according to clinical report [1] (Figure). Averaged values of the elastic modulus and ultimate stress data of the cortical and cancellous bones for different ages were obtained

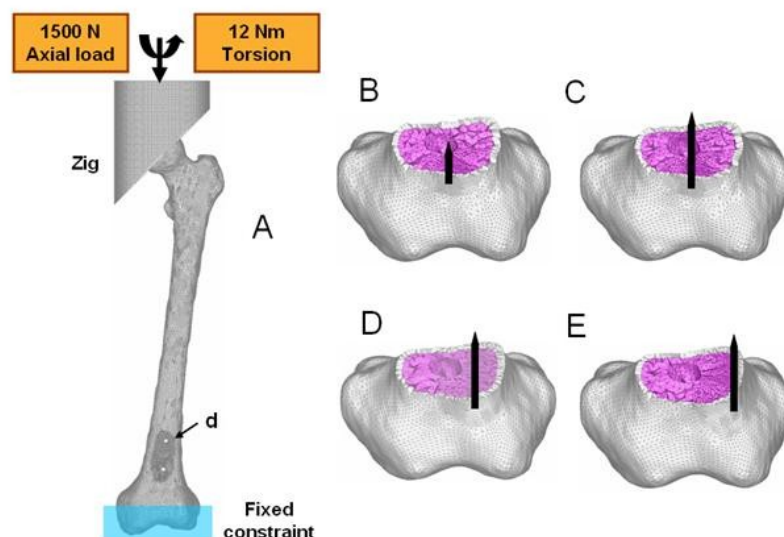


Figure: (A) Finite element model of femur with loading and boundary conditions.
(B)-(E) Four different modes of pin penetration in tubular bone;
(B) unicortical, (C) bicortical, (D) half-bicortical, and (E) transcortical.

from previous experimental study [3]. The elastic moduli were 15.5, 14.3, 14.0, and 13.7 GPa for cortical bone and 279, 145, 115, and 79 MPa for cancellous bone of 20, 60, 70 and 80 years,

respectively. The ultimate stresses were 122, 98, 91, and 85 MPa for cortical bone of 20, 60, 70 and 80 years, respectively. 1500 N of axial compressive force and 12 Nm of axial torsion were applied at the femoral head and the bone was rigidly fixed to a 20 mm above the distal end. The finite element analyses were performed using ABAQUSTM (Standard 6.5, ABAQUS Inc., USA). The percent ratios of maximum von-Mises stresses to ultimate stresses were compared for different pin penetration modes to investigate the stress fracture risk for different ages.

Results: Under axial load, the ratio of maximum von-Mises stresses to ultimate stresses showed as 6.5 - 9.6%, 15.7 - 22.3%, 14.7 - 20.9% and 18.7 - 29.1% in the 3 mm pin-diameter, and 7.0 - 10.5%, 14.6 - 20.9%, 14.2 - 20.3% and 26.0 - 42.1% in the 4 mm pin-diameter from 20 years to 80 years in unicortical, bicortical, and transcortical penetrations, respectively. Under torsion, the ratio of maximum von-Mises stresses to ultimate stresses showed as 9.0 - 13.4%, 9.0 - 13.4%, 7.8 - 12.5%, and 13.7 - 19.7% in the 3 mm pin-diameter, and 8.4 - 12.5%, 8.7 - 12.9%, 9.4 - 13.8% and 20.7-29.9% in the 4 mm pin-diameter from 20 years to 80 years in unicortical, bicortical, and transcortical penetrations, respectively. In the transcortical penetration, the larger pin diameter elevated fracture risk ratio dramatically in both axial load and torsion

Discussion: In this study, aging effect was shown to increase the femoral stress fracture risk for all pin penetration modes. For all cases, transcortical pin penetration mode showed the highest stress fracture risk. In addition, Aging effect was shown dramatically in the transcortical pin penetration mode. This result supported to the clinical report which presented the femoral fracture under the transcortical pin penetration mode. From our study, it is necessary to carefully consider the pin-hole in aged or osteoporotic bone to avoid the transcortical pin penetration mode with bigger diameter [2].

Acknowledgement: This work was supported by the Basic Science Research Programs (R01-2008-000-20352-0) through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology.

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