THE INFLUENCE OF POST-CAM DESIGN FEATURES ON STRESSES IN TIBIAL POST OF POSTERIOR STABILIZED KNEE PROSTHESES- A FINITE ELEMENT ANALYSIS

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Introduction:  
Posterior-stabilized (PS) total knee arthroplasties (TKAs) have been shown with satisfactory long-term survival rates and good functional performance. The engagement of tibial post and femoral cam in the PS knees provides posterior stability in flexion, restores normal posterior femoral rollback and thus results in larger range of motion. However, recent retrieval studies of the PS knee prostheses seemed to indicate that the tibial post wear was one of the factors that contributed to the risk of osteolysis and loosening. There are few biomechanical studies involving the evaluation of stress distribution at the tibial post of PS knee prostheses. Therefore, this study aimed to evaluate the stress distributions on tibial posts with different post-cam design features of PS knee prosthesis.

Methods:  
Two finite element models of PS tibiofemoral component were constructed. Two design features of post-cam mechanism (Figure 1) were compared, one is flat on flat design (FF model) and the other is curve on curve (CC model). The program used for analysis and post-processing was ABAQUS 6.4-1. Convergence test was performed to verify as the solution did not appreciably change with mesh refinement (less than 2% of change for peak contact stress). Geometry and material nonlinearities were used in the analysis. The material property of polyethylene insert was set as an elastoplastic behavior of fourth-order polynomial relationship with a Poisson’s ratio of 0.45.

Two contact situations were simulated, the neutral contact was defined as no axial tibiofemoral rotation occurred and the axial tibial rotation was defined as the tibial insert with 10 degrees of internal rotation relative to the femoral component. An anterior shear force of 500 N was applied to the femoral component at 60, 90, 120 and 150 degrees of flexion. The bottom of tibial insert was fixed in all degree of freedoms. The femoral component was constrained to move along anteroposterior direction only. The von Mises stress, peak contact stress and maximum principal stress on the tibial post were calculated to compare the different post-cam features.

Results:  
In neutral contact situation, the von Mises stress of the FF model at 60, 90, 120 and 150 degrees of knee flexion were 21.1, 23.2, 20.4, and 27.6 MPa, respectively. For CC model were 20.4, 21.1, 20.5 and 21.6 MPa, respectively. The stress in FF model raised following increase of flexion angles, except for 120 degrees of knee flexion. The change of the von Mises stress was less pronounced in CC model. The increment of von Mises stress (10.7%) and peak contact stress (7.2%) were not obvious in the CC model, because the contacting surfaces of polyethylene insert was set as an elastoplastic behavior of fourth-order polynomial relationship with a Poisson’s ratio of 0.45.

Discussion:  
The post-cam mechanism in the PS knee design was to increase posterior stability and to increase femoral posterior translation. The post wear and potential fracture of the tibial post due to the load-bearing engagement with the femoral cam in the PS knee were also shown. There were few literature reported the stress in knee prosthesis at high flexion angles. This study was therefore aimed to evaluate stresses at the tibial post of PS knee prostheses.

The results showed that very high von Mises stress and peak contact stress at tibial post in FF model at high flexion angle, especially when axial tibial rotation was simulated (Figure 3). Comparing the stresses on the tibial post at axial tibial rotation with those at neutral contact situation of FF model, the greatest increment of von Mises stress was 126.3% and peak contact stress was 151% at 120 degrees of flexion. Such stress increase in the FF model was almost 2 times at whole knee flexion angles because the FF model could only provide an ideal contact in the neutral contact. At the high flexion angle of the axial tibial rotation condition, the femoral cam of the FF model got to pin on the posterior corner of tibial post and resulted in stress concentration. The increment of von Mises stress (10.7%) and peak contact stress (7.2%) were not obvious in the CC model, because the contacting surfaces of tibial post and femoral cam are both curved surfaces that can reduce edge loading on the corners of tibial post. The curve on curve contact of post-cam mechanism has lower contact stress and tensile stress than those of flat on flat design, especially in axial tibial rotation simulation. Curve on curve design offers an advantage of reducing edge loading at post-cam mechanism over flat on flat design to accommodate axial tibiofemoral rotation of knee joint.

References: