ROUND TIBIAL POST CAN REDUCE CONTACT STRESS IN THE POST-CAM STRUCTURE IN POSTERIOR STABILIZED TOTAL KNEE ARTHROPLASTY

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Introduction: Posterior stabilized (PS) type knee prosthesis characterized by Post-Cam structure as stabilizer has successfully been used in total knee arthroplasty (TKA) worldwide, while failure and fracture problems of tibial insert made from polymeric material (UHMWPE) are still important issues from clinical and mechanical points of view. It is therefore needed to understand the mechanical conditions of the tibial insert under different kinds of TKA motions. The aim of this study is to characterize the mechanical condition of tibial insert under contact between femoral component and tibial insert during flexional motion using dynamic 3-D finite element (FE) method. 3-D FE models of two different kinds of PS type prostheses clinically used were developed and stress analyses were performed from full extension to 135° knee flexion. Effects of the different Post-Cam structures on the stress states were then investigated, and a guideline towards risk assessment of PS type prosthesis was discussed.

Materials and Methods: 3-D FE models of Stryker’s PS type knee prostheses, Scorpio Superflex and NRG, were developed based on their CAD data. Superflex has an angular tibial post and NRG has a round post. NRG can be regarded as a modified version of Superflex so as to reduce stress concentration in the tibial insert and therefore improve the durability and mobility. The femoral and tibial components were assumed to be rigid and the tibial UHMWPE insert to be elastic-plastic. The elastic-plastic constitutive model was constructed from an experimental data for UHMWPE. Four nodes tetrahedral elements were used to construct the FE models. The boundary conditions are shown in Fig.1. Nonlinear spring models were attached to the front and back of the tibial component to express the effect of soft tissues on the movement of real TKA knee (1). Vertical load P1 and horizontal load P2 were applied to the femoral and tibial components, respectively, to express a deep knee bending (squatting) motion (2). Flexion motion was introduced by rotating the femoral component from full extension to 135°. Internal rotation of 5°, 10° and 15° was also introduced by rotating the tibial component simultaneously with the flexional motion.

Results: Maximum Mises equivalent stress during knee flexion with 5°, 10° and 15° internal rotation of the tibial component are shown as a function of flexion angle in Fig.2. Mises equivalent stress distributions at 135° only and 135° with 10° internal rotation are shown in Fig.3. For Superflex, severe stress concentration was observed on the Post surface due to Post-Cam interaction. High stress concentrations were also generated on the condylar surfaces. It was found that the maximum stress was much higher with internal rotation than without it. Effect of internal rotation can also be recognized as the inclined stress distributions on the surfaces. NRG exhibited stress concentrations on both the Post and condylar surfaces and the stress levels were much lower than that of Superflex. The maximum stress in NRG was found to be reduced to about half of Superflex.

Discussion: It has been reported that the tibial component rotates up to about 15° during knee flexion. The analytical results well demonstrated that the design modification of the tibial insert of NRG effectively reduced the stress concentration even with rotated tibial component. The lower stress level in NRG corresponds to the lower reaction force and hence lower resistance to flexional motion than Superflex. This implies that the round post is more suitable for deep flexion than the angular post.

The dynamic simple 3-D FE model of PS type prosthesis developed in this study successfully expressed the difference of mechanical behavior between Superflex and NRG during knee flexion. It is also emphasized that this FE model can easily include different types of knee motions by changing the boundary conditions. It is thus concluded that this FE model can be a useful tool for risk assessment of PS type knee prosthesis.