Effect of Loading Variability on Stress on Tibial Polyethylene Component in Posterior Stabilized Total Knee Replacement

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INTRODUCTION

Recently, it has been reported that posterior stabilized (PS) total knee replacement (TKR) may have failure risk such as wear of fracture caused by the focused pressure and stress on the tibial post [1-4]. Malalignment of the implant or variable loading applied to the implant are one of the major causes of the failure in PS TKR. The objective of this study is to understand how much the loading variability of the implant influences the stress of the tibial polyethylene component in the PS TKR by finite element analysis.

METHODS

The finite element model of a knee, including tibia, femur, patellar, patella tendons, medial and lateral collateral ligaments, was developed from 1mm slices of CT image by using 3D-Doctor®(Able Software Corp., USA). The bone segments were assumed as linear elastic and ligaments were considered as non-linear springs. The finite element model of implant (United Orthopedic Corp., Taiwan) was developed by using SolidWorks® (Solidworks Corp., USA) and FEMAP® (V8.2, EDS Corp., USA). The PS implant consists of a femoral component, a tibial post, and a tibial tray made by Co-Kr, UHMWPE, and Co-Cr-Mo, respectively. The material properties of the knee and implant models were taked from previous studies. For the neutral axis of the knee, femur is rotated by 5° of valgus in coronal plane. The default loading condition at the 40% of one whole gait cycle, which is 2000N of compressive load, 25N of anterior-posterior load, and 6.5Nm of torque, was applied to the TKR model. For the boundary condition, the TKR model was constrained in flexion or extension and proximal femur was fixed. In addition to the neutral model, different oblique loading cases (3° and 5° of valgus and varus angulations, 2° and 4° of anterior and posterior tilts, and 3° of external rotation) were considered for the analysis. The maximum von-Mises stress values were obtained to investigate the effect of loading variability on the stress distribution of the tibial polyethylene component in the PS TKR.

RESULTS

The maximum von-Mises stresses were concentrated on the anterior region of the tibial post regardless of the oblique loadings. In the rotationally additional loading (3° of external rotation), excessive stresses occurred in the anterior medial and posterior lateral areas.

The maximum stresses was 18.3MPa in neutral position. The maximum stress increased by 10% in anterior tilt 2°, 15% in anterior tilt 4°, 25% in posterior tilt 2°, 54% in posterior tilt 4°, 116% in varus 3°, 262% in varus 5°, 318% in valgus 3°, 389% in valgus 5°, 6% in external rotation 3° compared with that in the neutral position case. In addition, 32.0MPa of maximum stress occurred on the posterior lateral area of the base component in rotational additional loading.

DISCUSSION

The results showed that any change of loading direction or additional loading could accelerate the stress concentration on the anterior region of the tibial post as in the result of clinical study [1]. In the case of additional rotation, high stress concentration on the anterior medial and posterior lateral areas as well as on the tibial base surface could generate wear or fracture risk of tibial post. This type of loading variability could be possible not only in the abnormal loading situations or malalignment of the implant in any directions. From the additional rotation case, we can expect that higher conformity implant will generate higher stress concentrations than lower conformity implant even though we did not compare the effect of conformity ratio on the stress concentration in the tibial polyethylene component. This study showed that careful consideration of the implant malalignment or abnormal loading change would be necessary to improve the clinical outcome in the PS TKR.

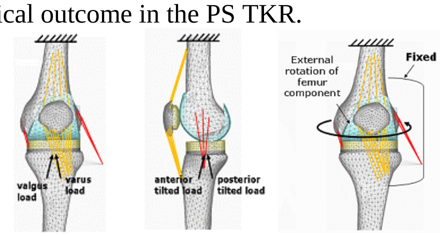

Fig. 1 Finite element models of knee with frontal and sagittal oblique loadings, and additional rotation

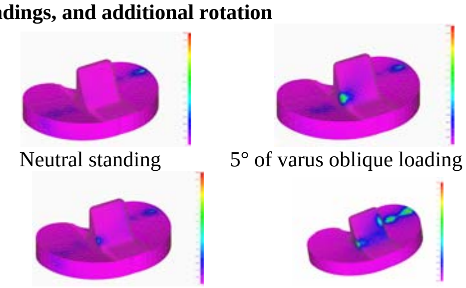

Fig. 2 Distributions of the maximum von-Mises stresses on the tibial polyethylene component for neutral standing, 5° of varus and 4° of posterior slope oblique loadings, and 3° of additional rotation

REFERENCES

[1] Clarke H D et al., J Arthrop, 19:652-7, 2004.
[2] Matsuda S et al., J Arthrop, 14:566-70, 1999.
[3] Halloran J P et al., J Biomech, 38:323-31, 2005.
[4] Chiu Y S et al. J Arthrop, 19:1045-9, 2004.
[5] Liau J J et al., Clin Biomech, 17:140-6, 2002

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