ABSTRACT INTRODUCTION:

To achieve natural knee kinematics including femoral rollback and tibial rotation was one of the major goals after total knee arthroplasty (TKA). It is believed that increase of femoral rollback would enhance the efficiency of quadriceps muscle and improve the performance of knee activity. Tibial rotation was associated with deep-flexion posture, such as squatting, kneeling or lunging. However, a phenomenon was observed that there was insufficient or inadequate of femoral rollback and tibial rotation after TKA. For achieving normal knee kinematics, asymmetrical designs such as fully flat, medial pivot and motion-guiding insert designs were developed to improve knee kinematics by modifying the articular surfaces of tibial inserts and femoral components. However, the aforementioned insert designs cannot reproduce normal knee kinematics sufficiently. Actually, the lateral tibial plateau of natural knee is convex shape on the posterolateral portion on the sagittal plane, whereas the medial condyle is concave shape [1]. Therefore, the purpose of current study was to construct a new articular surface, then investigate the influence of geometrical change of articular surface on knee kinematics. We believed that anatomic-like insert design could be expected to restore femoral rollback and tibial rotation and perform more like intact knee.

METHODS:

Imaging data were taken from a healthy right knee of a female. Bony and cartilaginous models of intact knee were reconstructed from sagittal magnetic resonance images by Amira 4.1. The slice interval of MR images was 1 mm and the resolution was 480x512 pixels. Thereafter, model was imported into MSC.ADAMS for dynamic simulation. Ligaments were modeled as fiber bundles and adequate force components with parabolic and linear regions [2]. The stiffnesses of quadriceps tendon and patellar tendon were simulated as 2000 N/mm and 1142 N/mm, respectively. The connective lines of extension facet centers (EFCs) and flexion facet centers (FFCs) were assigned as femoral flexion axes. The femoral flexion axes of TKA models were in compliance with the condylar radii of femoral component. The constraint of tibial component was allowed unconstraint except for the flexion-extension. The average ground reaction force (1.5 body weight) was applied to the center of mass on the tibial component (Fig.1A). The friction coefficients of cartilage-to-cartilage and metal-to-polyethylene surfaces were simulated frictionless and 0.04, respectively. In order to avoid the wrapping of quadriceps tendon around the trochlear groove at higher knee flexion, multiple beads connected by springs were used (Fig.1B). TKA model was implanted with U2 Total Knee System-CR type (United Co., Hsinchu, Taiwan) referring to their guidance of standard surgical procedure and assigned as CON model. The new anatomic-like knee (ALK) model was modified from the CON model. The geometric shape of the articular surface at posterolateral tibial insert of ALK model was changed to a convex shape and the medial articular surface remained unchanged (Fig.2).

RESULTS SECTION:

Results of lateral femoral movement are shown in Fig. 3. The largest posterior movements were 16.7 mm for intact knee, 5.8 mm for CON model and 10.4 mm for ALK model at 120° flexion. Maximal increase of lateral femoral movement for ALK model was 4.6 mm at 120° flexion when compared with CON model. For the medial condyle, unchanged insert articular surface of ALK model has similar femoral movement to CON model. The results of tibial rotation are shown in Fig. 4. The largest rotational angles were 10.3° at 80° flexion for CON model, 20.3° and 13.5° at 120° flexion for intact and ALK models, respectively. Maximal increase of tibial rotation for ALK model was 8.1° internally at 120° flexion when compared with CON model.

DISCUSSION:

The long-term survivor rate of TKAs has been reported to be over 90% in ten years, and restoration of normal knee kinematics after TKA is essential concern. However, many studies demonstrated that femoral rollback and tibial rotation were difficult to restore after TKA. The reason is likely to be the morphological differences between two sides of knee joint. The main difference between the medial and lateral compartments is that the medial tibial plateau is slightly concave, whereas the lateral is convex. The anatomic-like knee prostheses design demonstrated that maximally enhances femoral rollback by 27% and internal tibial rotation by 40% of intact knee when compared with the symmetrical CON model. The new anatomic-like insert design can be expected to restore normal knee kinematics.

REFERENCES: