Influence of femoral cam shape on axial tibiofemoral rotation in posterior-stabilized TKA

INTRODUCTION:
Posterior-stabilized total knee arthroplasty (PS TKA) is a successful procedure with satisfied outcome and good performance. Even though the endurable longevity, patients may expect more restoration for activities of daily living, particularly in non-Western populations. It was revealed that deep-flexion activities such as squatting, kneeling, and sitting cross-legged are required in Asia and the Middle East. These positions demand sufficient femoral rollback and axial tibiofemoral rotation.1,2 Nevertheless, knee kinematics after PS TKA was inconsistent with that of the intact knee and the flexion range was rarely more than 120°.3-5 Specifically, clinical literatures showed that tibiofemoral rotation was significantly reduced when compared with the intact knee.3-5 The relative axial motion of the tibia and the femur had been verified that it would to be guided by post-cam mechanism.6 For post-cam design, it is crucial to provide adequate tibiofemoral rotation to assist the achievement of high knee flexion. We proposed an asymmetric femoral cam for PS TKA and hypothesized that this design could accommodate tibiofemoral rotation. This study therefore aimed to investigate our hypothesis for the asymmetric cam design.

METHODS:
CAD model of a PS knee system (United Orthopedic Corporation, Taipei, Taiwan) was reconstructed and the post-cam design was modified as curve-on-curve contact feature, which was defined as baseline model. The asymmetric model was then derived from reducing the medial side of the curved femoral cam. A dynamic knee model used in our previous study was utilized for kinematics analysis.7 CAD models of the two prostheses with different femoral cam shape were virtually implanted in the knee model referring to standard surgical procedure. Surrounding soft tissues including collateral ligaments, patellar tendon, and quadriceps tendon were modeled as non-linear springs.8 Flexion facet centers of medial and lateral condyles in the PS knee defined the flexion axis. The motion of the femur was confined to rotate about the flexion axis. The tibia could move freely except for flexion. The analysis was carried out from 0° to 150° of knee flexion. Kinematics data including anteroposterior condyle movement and axial tibiofemoral rotation during whole knee flexion were recorded.

RESULTS:
Femoral condyle movements in two femoral cam designs represented paradoxically anterior translation before post-cam engagement, especially in medial condyle. The amount and major trend of femoral translation were similar in both designs. After post-cam engagement, posterior femoral movement was restored. At 150° of flexion, the lateral femoral condyle translated 18mm posteriorly in the baseline and 23mm in the asymmetric model. Medially, posterior translation of femoral condyle in the baseline model was 7.5mm at 15° of flexion and it was -2mm in the asymmetric model. With regard to tibiofemoral rotation, the rotation angle was similar in both designs before post-cam engagement (Fig 3). At 150° of flexion, tibiofemoral rotation of the baseline model was 12°, while the asymmetric model exhibited 23° of internal tibial rotation.

DISCUSSION:
Deep-flexion activities were necessary in non-Western cultures and this demand may also increase due to younger in the age of patients subjecting to TKAs. However, the reported range of motion after TKA was commonly less than 120° of flexion. Poor knee kinematics was revealed, specifically for axial tibiofemoral rotation.3-5 Current study investigated the influence of femoral cam shape on knee kinematics. As expected, the results showed that the asymmetric design could improve internal tibial rotation, while the baseline model exhibited decreasing rotation angle beyond post-cam engagement. This phenomenon indicated that reduction in the medial side of the femoral cam could provide a better relative motion for post-cam articulation. As for femoral movement, paradoxically anterior translation of the femur was observed in both designs at initial flexion angles. This would compromise total amount of posterior femoral movement and result in unstable perception for the patient during knee flexion. After post-cam engagement, the baseline model exhibited significant restoration of posterior translation in both condyles, whereas the medial condyle of the asymmetric model was located anteriorly. Sufficient femoral rollback is one of critical factors for high knee flexion. Inadequate amount of the medial condyle in the asymmetric model would lead to early impingement between the femur and the tibia jeopardizing knee flexion range. Some limitations of the present study must be considered. First, two specific designs in this study cannot represent all design features of contemporary knee prostheses. Second, rigid bodies were assumed for the tibial and femoral components and simulated in the study, thus the results can not reflect the influence of different materials. Third, the knee motion simulated in this study cannot represent actual situations in daily living such as squatting. Obitrating these limitations, current study provided guidance in designing PS knee to help for achieving more normal knee kinematics. In conclusion, the hypothesis that the asymmetric design of the femoral cam could accommodate tibiofemoral rotation during knee flexion was well verified. It may certainly eliminate rotational constraint in post-cam mechanism. However, paradoxically anterior femoral translation was observed and total posterior translation of femoral condyle was compromised. Further modification of PS knee prosthesis is still essential for the requirement of high knee flexion.

REFERENCES: