A newly post-cam mechanism of PS TKA designed to improve knee kinematics

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INTRODUCTION:
More restoration for activities of daily living has been great of concern, 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. Nevertheless, knee kinematics after total knee arthroplasty (TKA) was inconsistent with that of the intact knee and the flexion range was rarely more than 120°. Recently, several investigations proposed different tibiofemoral design features with the goal of improving knee kinematics.1,4 However, the amount of femoral roll-back and internal tibial rotation was still inadequate when compared with the intact knee. Based on the authors’ previous studies,1 a newly post-cam mechanism of posterior-stabilized (PS) TKA was proposed. It was hypothesized that this design could enhance femoral roll-back and accommodate better tibiofemoral rotation. This study therefore aimed to investigate the hypothesis for the newly post-cam design.

METHODS:
The proposed post-cam mechanism was modified from a PS knee system (United Orthopedic Corporation, Taipei, Taiwan). The design concept of the mechanism was come from the ball-and-socket mechanism, an unrestrained rotational joint. Based on this concept, the tibial post was modified from a spherical shape whereas the femoral box was formed a closed box corresponding with the tibial post (Fig 1). In addition, the femoral fox was modified to engage with the post at 30° of knee flexion. A dynamic knee model used in our previous study was utilized for kinematics analysis.1,5 CAD models of the PS knee with newly mechanism 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 fore elements.2

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. The kinematics data was compared with two contemporary post-cam designs, curve-on-curve and flat-on-flat contact surfaces, which were analyzed in our previous publication.

RESULTS:
Knee kinematics between the newly design and the two contemporary designs were significantly different. Initial engagement of the post-cam occurred at flexion 28° in the newly design and it was approximate 80° in the two contemporary designs.

Femoral condyle movements in the newly design represented approximately normal motion pattern of the intact knee. The medial condyle translated 4 mm anteriorly at early flexion while the lateral condyle exhibited significantly posterior movement. At 150° of flexion, the lateral femoral condyletranslated 25 mm posteriorly while it was 5 mm in the medial condyle. Oppositely, paradoxical anterior sliding of the femur was observed in the contemporary designs at initial flexion angles. The amount of femoral roll-back and internal tibial translation was still inadequate when compared with the intact knee. This phenomenon indicated that the geometry of the newly design with early engagement could provide a better relative motion for post-cam articulation.

As for femoral movement, paradoxically anterior translation of the femur was observed in the contemporary 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. In contrast, this phenomenon was eliminated in the newly mechanism with an early engagement consideration. Great amount of posterior femoral translation was restored. Sufficient femoral rollback is one of critical factors for high knee flexion. High demanded activities may be achieved with the newly design.

Some limitations of the present study must be considered. First, 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. Second, the knee motion simulated in this study cannot represent actual situations in daily living such as squatting. In conclusion, the hypothesis that the newly geometry of the post-cam mechanism could accommodate better tibiofemoral rotation and restore more femoral roll-back during knee flexion was well verified. It may certainly eliminate rotational constraint in contemporary post-cam design. Further biomechanical investigation of the newly design is still essential for ensuring low wear risk of the polyethylene post.

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, poor knee kinematics was revealed, specifically for axial tibiofemoral rotation. Although several efforts were done to improve knee kinematics, the amount of femoral roll-back and tibial rotation was insufficient.

Current study investigated the knee kinematics of a newly post-cam mechanism. As expected, the results showed that the newly design could improve internal tibial rotation, while the two contemporary designs exhibited decreasing rotation angle beyond post-cam engagement. This phenomenon indicated that the geometry of the newly design with early engagement could provide a better relative motion for post-cam articulation.

REFERENCES: