In Vivo Determination of the Cam-Post Engagement in PS Mobile-Bearing TKA

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INTRODUCTION: The cam-post mechanism has been introduced to the total knee arthroplasty (TKA) in order to provide posterior stability of the femoral component. It has been hypothesized that the femoral cam will engage with the tibial post, preventing the femur from sliding anteriorly and providing posterior femoral rollback that is necessary for achieving deep flexion of the knee. Based on this hypothesis, a large number of computer simulations and in vitro studies have been performed to test the stress and fatigue resistance of the polyethylene, so that the tibial post design can be improved. However, the in vivo data pertaining to the actual cam-post engagement mechanism is still very limited. Therefore, the objective of this study was to determine the cam-post mechanism interaction under in vivo, weight bearing conditions.

METHODS: In vivo, weight bearing knee kinematics were determined for eight subjects (9 knees, 6 females, 2 males) having a Sigma Rotating Platform PS TKA (DePuy, Warsaw, IN). The participants performed deep knee bend activity while under fluoroscopic surveillance. The 3D kinematics was recreated from the fluoroscopic images using previously published 3D-to-2D registration technique [1]. In order to determine the polyethylene insert location and orientation, 4 metal beads were imbedded into the polyethylene insert prior to the replacement surgery. Images from full extension to maximum flexion were analyzed at 10° intervals. Once the 3D kinematics of all implant components was recreated, the analysis focused on the cam-post mechanism. The distance between the interacting surfaces was monitored throughout the flexion and the predicted contact map was calculated (Fig. 1). The instances, when the minimum distance between the cam and post surfaces dropped to zero was considered to indicate the engagement of the mechanism.

For more even comparisons of the results between the subjects, the relative kinematics of the components was determined using Grood and Suntay convention [2, 3] and the data was matched with respect to the actual tibiofemoral flexion. The axial rotations of the femoral and polyethylene insert components were calculated relative to the tibial component.

RESULTS: The average maximum flexion achieved by the subjects was 105.9° (SD=13.2°). The cam-post mechanism engaged between 90° and 105° of knee flexion and the two components remained in contact until the maximum flexion was achieved (Fig. 2). Only one subject did not experience cam/post engagement (the minimum distance was 2.2mm at 86° of flexion, which was the maximum for this subject). After the cam engaged with the post, the contact location moved superiorly with increasing knee flexion. It was further observed that the contact area was located centrally on the post.

On average, the axial rotation of the femur increased from 0.8° (SD=3.5°) to 9.2° (SD=2.7°) from full extension to maximum flexion (Fig 3). The average axial rotation of the polyethylene insert also increased with the knee flexion; from 3.1° (SD=3.9°) at full extension to 9.3° (SD=6.3°) at maximum flexion.

DISCUSSION: The cam-post interaction was found to be very consistent among the subjects, and the stabilizing mechanism engaged in deeper flexion (between 90° and 105°). Interestingly, for one subject the cam did not come into contact with the post even though the subject achieved its maximum weight bearing flexion. This was probably due to limited flexion achieved by this subject (86°) and was still consistent with the patterns observed for other subjects, because the cam was also not in contact for all other subjects at this flexion angle. It was also observed, that once the two components engaged, they remained in contact until maximum flexion was achieved.

It was further observed, that the contact between the cam and post was located centrally on the post at all times when engaged. This is probably due to the mobility of the polyethylene, characteristic for the analyzed TKA design. The polyethylene insert rotated axially in accord with the rotating femur (Fig 3). Therefore the posterior surface of the mobile bearing post was able to remain parallel to the surface of the femoral cam. As a result the stresses imposed on the polyethylene insert could be distributed more evenly and over larger area, which could increase the longevity of this component. Such conditions may conceivably be difficult to achieve for fixed bearing PS TKA, where the femoral component rotating externally may cause the cam post mechanism to engage more medially, increasing the edge loading on the polyethylene.

References: