In Vivo Determination of Cam-Post Engagement in PS, BCS and Bi-Surface TKA

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INTRODUCTION
Posterior stabilized (PS) total knee arthroplasty (TKA) provides posterior stability with the use of a cam-post mechanism which performs the function of the posterior cruciate ligament. The tibial post engages with the femoral cam, prevents the femur from sliding anteriorly and provides the posterior femoral rollback necessary for achieving deep flexion of the knee. However, these designs do not substitute the resection of the anterior cruciate ligament. In order to overcome this deficit, other TKA designs have been recently introduced to provide dual support, with the help of dual cam-post engagement mechanism.

Various studies conducted on the PS TKA have suggested that the cam-post mechanism does not engage as designed, resulting in tibial post wear and increased stresses resulting in backside wear of the polyethylene insert component. Also, the in vivo data pertaining to the actual cam-post engagement mechanism in bi-cruciate stabilized and bi-surface knees is still very limited. Therefore, the objective of this study was to determine the cam-post mechanism interaction under in vivo, weight bearing conditions for subjects implanted with either a Rotating Platform (RP) Posterior Stabilized (PS) TKA or a bi-cruciate stabilizing TKA (BCS).

METHODS
In-vivo, weight-bearing, 3D knee kinematics were determined for eight subjects (9 knees) having a RP-PS TKA (DePuy Inc.) and eight subjects (10 knees) having BCS TKA (Smith&Nephew Inc.) and ten subjects (10 knees) having a Bi-surface TKA (Japan Medical Materials Inc), while performing a deep knee bend. 3D kinematics was recreated from the fluoroscopic images using a previously published 3D-to-2D registration technique. Images from full extension to maximum flexion were analyzed at 10° intervals. Once the 3D kinematics of all implant components was recreated, the cam-post/ third condyle (for Bi-surface TKA) mechanism was scrutinized. The distance between the interacting surfaces was monitored throughout the flexion and the predicted contact map was calculated. The instances, when the minimum distance between the cam and post surfaces dropped to zero was considered to indicate the engagement of the mechanism. This analysis was carried out for both the, anterior and posterior cam-post engagement sites.

RESULTS
Anterior Contact (BCS TKA): Seven of the 10 knees analyzed had the femoral component engaged with the anterior aspect of the tibial post at full extension (Figure 1). However, the contact between them was lost in very early flexion (average: 4.9°; maximum: 9.9°). The contact was always located centrally on the anterior aspect of the tibial post.

Posterior Contact: The cam-post engaged at 34° for the BCS, 66° for the Bi-surface and at 97° for RP-PS TKA. In the BCS knees, the contact initially occurred on the medial aspect of the tibial post and then gradually moved centrally and superiorly with increasing flexion, while for the RP-PS TKA it was located centrally on the post at all times (Figure 2). For the Bi-surface group, the contact of the third condyle initially occurred on the medial side and moved centrally (Figure 3), often resulting in a lift-off of the lateral condyle. There were two subjects in the BCS group who had engagement during mid-flexion (50-90°), but, lost contact with the post between 100-110°, before regaining contact in deeper flexion.

DISCUSSION
The anterior cam-post interaction in the BCS group was found to be present in a majority of subjects. However, there were three subjects who did not have any contact with the anterior aspect of the tibial post. On the posterior side, contact was established by all subjects analyzed in the BCS and Bi-surface groups and 8/9 subjects analyzed in the RP-PS group. Also, for the BCS and Bi-surface groups the initial contact with the tibial post was achieved on the medial aspect, before the contact area tended to move centrally and superiorly (for BCS) with increasing flexion. This could be due to the large amount of lateral PFR combined with lesser amounts of medial PFR (femoral component rotating externally) experienced by the subjects. Therefore, the posterior surface of the tibial post was not parallel to the femoral cam surface. Interestingly, in the RP-PS group, 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. Therefore the posterior surface of the mobile bearing post was able to remain parallel to the surface of the femoral cam. This phenomenon in the BCS group (Fixed bearing TKA) may increase the chances of edge loading on the polyethylene, resulting in wear patterns on the post. This is the first study that investigates the interaction of the “third condyle” of a Bi-surface TKA.