INTRODUCTION
The contribution of basic bone and soft tissue morphology to knee flexion is not well understood. The purpose of this study is to examine how parameters defining the bony morphology of the femur and tibia influence the kinematics of the knee in high flexion.

METHODS
Twelve fresh-frozen lower limb specimens were examined arthroscopically to confirm the presence of an intact ACL, and absence of degenerative changes in the medial and lateral compartments and the patellofemoral joint. Each knee was mounted in a 6 degree-of-freedom squatting simulator and loaded with a system of 4 external forces generating flexion from full extension to maximum flexion. During this activity, the three-dimensional positions of the femur, patella and tibia were tracked in real time using a motion analysis system (NDI).

3D computer models of each knee were created by reconstructing CT scans of each specimen and registered with the measured position of each bone during the high flexion activity. Morphologic parameters describing the femur and tibia were measured for each specimen and correlated with kinematic variables describing the position of each specimen at terminal flexion. All kinematic variables describing the relative position and orientation of the tibia with respect to the femur were calculated using the axis convention of Grood and Suntay.

RESULTS
For the twelve specimens, maximum knee flexion averaged 145±11° (range: 124° to 157°). In this position, posterior rollback of the femur averaged 20±7mm (range: 7mm to 32mm), with 18±5° of internal tibial rotation (range: 7° to 23°). Interestingly, there was a significant negative correlation between tibial rotation and maximum knee flexion (r=−0.6, p=0.0279).

Morphologically, the medial and lateral posterior femoral condyles had the same radius (medial: 22.6±3.1mm; lateral: 23.7±1.7mm; p=0.19). However, the medial femoral condyle extended 3.8±2.3mm further posteriorly than the lateral femoral condyle (p=0.0002).

The average length of the tibial plateau was 48.6±5.7mm medially vs. 40.8±4.7mm laterally. The lateral plateau was found to consist of two areas of articulation: an anterior articulation of similar slope (8.4±1.1°) and 90% of the area of the medial plateau, and an oblique posterior facet oriented at 28±7° to the anterior plateau and occupying 15% of its surface area. The average length of the posterior facet was 6.0±1.5mm in the anteroposterior direction.

Correlation analysis demonstrated that the strongest predictor of terminal flexion was decreased girth of the thigh and calf (r=−0.9, p<0.007). However, knee flexion also increased with the notch radius, corresponding to the junction between the posterior condylar surface and the posterior femoral cortex (r=−0.8, p<0.03). In addition, an increased condylar offset from the posterior cortex and an increased posterior tilt in the posterolateral tibial facet was also associated with increased terminal flexion.

DISCUSSION
Many factors affect the terminal flexion attainable in the intact knee. Clearly, the size of the calf and the thigh limit the range of motion of the knee, but other bony morphological features also play a role, particularly the geometry of the posterior femur and the lateral posterior tibial facet. These observations are critical for designing arthroplasty components and orienting them correctly on the host bones, such that higher flexion angles are achievable. We observed that the posterior condylar offset was larger on the medial side by an average of 4mm.

 Routinely placing femoral components in three degrees of external rotation effectively decreases the posterior condylar offset on the medial side and effectively increases the lateral offset, thus changing and potentially reversing this difference. This is a potential explanation for decreases in terminal flexion following TKA.

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