INTRODUCTION:
The tracking of the patella relative to the femur is strongly influenced by the geometry of the trochlear groove. Nonetheless, few studies have examined the quantitative correlation between the three-dimensional geometry of the trochlear groove and patellar tracking, particularly under in vivo conditions. Accurate knowledge of this correlation can help delineate the relationship between morphological abnormalities of the trochlea and patellar maltracking [1, 2]. Additionally, it could also enable better understanding of the link between total knee arthroplasty (TKA) implant design/placement, and the resulting patellar tracking [3,4]. The aim of this study was to measure patellar tracking in living subjects during weight-bearing knee flexion, and to quantify its relationship to the trochlear groove geometry of the subjects’ knees.

METHODS:
Twenty one subjects (10 male, 32.2 ± 7.1 yrs; 11 female, 29.6 ± 10.8 yrs) were recruited following approval by our institute review board and informed consent was obtained. Magnetic resonance scans were used to create subject specific 3D models of the femur and patella. Subsequently, the subjects performed a single leg lunge while their knee was imaged using a dual fluoroscopic imaging system [5]. The femur and patella models were then matched to the fluoroscopic images, and motion of the patella relative to the femur was measured at five knee flexion angles between 30° and 105°. Three patellar tracking parameters were measured: patellar shift relative to mid-point of femoral transseptional axis (TEA), patellar tilt relative to TEA measured in plane passing through TEA and patellofemoral contact centroid, and patellar rotation relative to TEA measured in plane perpendicular to that passing through TEA and patellofemoral contact centroid (Fig. 1). Next, mediolateral sulcus location, trochlear bisection angle and trochlear coronal plane angle were measured at the cross-section through the TEA and corresponding patellofemoral contact centroid. To measure the coronal plane angle, the deepest points of the trochlea were projected onto the coronal plane of the femur using a rollout projection. The slope of a curve fit to the projected points, measured relative to a line perpendicular to the TEA, was defined as the trochlear coronal plane angle. A stepwise multivariate regression analysis was used to investigate the correlation of each patellar tracking parameter with all three geometric parameters, retaining only those geometric parameters that made significant contribution to the regression.

RESULTS:
The results showed that in the transverse plane, patellar shift was strongly correlated (correlation coefficient R = 0.86, p<0.001) to mediolateral location of the trochlear sulcus (raw regression coefficient b = 0.62), and the trochlear bisection angle (β = 0.31, Fig. 2). The regression equation indicated that for a fixed trochlear bisection angle, a 1 mm lateral shift of the trochlear sulcus would lead to 0.6 mm lateral patellar shift (Fig. 2). Similarly, for a fixed mediolateral location of the sulcus, a 1° increase in bisection angle would lead to 0.3 mm lateral patellar shift. Patellar tilt showed a significant association with the trochlear bisection angle (R = 0.45, p<0.001, β = 0.6), with the slope of the regression line indicating that an average 1° increase in bisection angle would lead to a 0.6° increase in lateral patellar tilt. However, in the coronal plane patellar rotation was poorly correlated to its matching geometric parameter, namely the coronal plane angle of the trochlea (R = 0.26, p = 0.01, β = 0.08).

DISCUSSION:
This is the first study to quantify the correlation between patellar tracking and trochlear groove geometry under in vivo conditions. All parameters were measured relative to planes passing through the patellofemoral contact centroid, thus avoiding the problem of projection artifacts associated with use of skyline views or 2D projections.

The results of this study showed strong correlation between transverse plane geometry of the trochlear groove (mediolateral sulcus location and bisection angle) and transverse plane motion of the patella (patellar shift and tilt). This may explain the strong association between femoral component malalignment and transverse plane patellar maltracking in TKA. Several studies have shown that a medialization/lateralization of component causes medial/lateral patellar shift, and external/internal rotation of the component causes a lateral/medial patellar shift and tilt [3,4]. However, in the coronal plane patellar rotation was weakly correlated to the coronal plane angle of the trochlea. This may explain why femoral TKA component malposition has shown to have little impact on patellar rotation while having a strong effect on patellar shift and tilt in the transverse plane [3,4].

Manufacturers of TKA continue to explore new designs. However, the relationship between design changes and in vivo patellar tracking are not fully understood. Therefore the results of this study could serve as a valuable reference for development of future implant designs. Furthermore, this knowledge may have important implications for treatment of patellar maltracking problems related to geometric abnormalities of the trochlea [1,2]. Currently, it is unclear as to what amount of deviation of the trochlear geometry from normal can lead to maltracking problems, and the amount by which the geometry should be corrected. The quantitative data presented in this study could serve as a starting point for future investigations into these issues.

REFERENCES: