The Aspherical Hip: An In-vitro Study
Sima Zakani
Department of Mechanical and Materials Engineering, Queen's University, Kingston, Canada

INTRODUCTION
According to Canadian Joint Replacement Registry (CJRR) [1], only in 2010-2011, there were 17,303 hip replacements performed in Canada with 10.1% revisions. More than 73% of these revisions were due to aseptic loosening, wear, and instability which raise the need for further investigation of hip biomechanics. The hip joint is often described as a “ball and socket” joint [2], which carries two key implications: congruent interacting bony joint surfaces and purely rotational relative motion [3]. This study challenges the kinematic description through investigating detailed motion of the hip joint during clinically relevant hip movements utilizing computer navigation technology.

METHODS
An in-vitro study was conducted using twelve fresh frozen cadaveric human hemi-pelvises, sectioned above L5 and at mid-femur with all the soft tissues intact. Three dimensional digital models of each specimen were generated through a systematic segmentation of computed tomography images, using Mimics software (Materialise, Leuven, Belgium). Local coordinate reference devices, mounted on the proximal femur and anterior-superior iliac spine, were tracked with an Optotrak active optical localization system (Northern Digital, Waterloo, CA). The position and orientation of the LCRs were then imported to custom virtual surgery software (iGo Technologies, Kingston, CA). The study used different soft tissue states as one variable and twelve gross passive motions as the other. The motions were combinations of flexion/extension, abduction/adduction and internal/external rotation. The entire series of motions were repeated for (I) soft tissues intact, (II) capsule intact and (III) completely disarticulated joint. Translation of the femoral head with respect to the acetabular cup at each frame was extracted from the recorded data. An Analysis of Variance (ANOVA) was used to determine whether the means of translations in each dissection states were significantly different.

RESULTS
Translatory motion was observed in all specimens. Significant differences were found between magnitudes of translation amongst various soft tissue states (p<0.001). Figure 1 shows decomposition of position and orientation data for a representative specimen as the femoral head was kept constant at 90 degrees flexion and taken through full abduction/adduction and full external/internal rotation. Highlighted areas indicate contact zones between the two articulating bones. Investigation of sudden changes in translational tracks of each femoral head, plotted as 2-D wave form, showed that there were correlation found between contact zones and excursions. Interestingly, three specific maneuvers were found to be more likely to cause maximal translations: ankle on knee (where the femur is flexed and externally rotated while being abducted), ankles crossed (where the femur is flexed and externally rotated while being adducted) and finally the pivot motion (where the femur is extended and externally rotated while the pelvis is abducted).

DISCUSSION AND CONCLUSIONS
The sub-millimeter accuracy computer navigation system facilitated detection of subtle translatory behavior in hip joint motion. The data provided evidence that femoral head translates with respect to the acetabular cup with or without any contact between the two bone, which was previously considered to be the main reason behind femoral excursions. The statistical significance found between translations exhibited at different soft tissue states is an indirect support of the aspherical adult hip, whose kinematics is driven by both soft tissue and the anatomy. The three specific motions that were found to lead to maximal translations have previously been reported to cause dislocation in patients undergoing total hip arthroplasties [4]. The results can be used to deduce that the arthritic hip does not have a ball-and-socket motion by an argument of contradiction. If the hip had a purely spherical motion due to articular shape, then changing soft tissues would not have disturbed this motion. This work towards an improved biomechanical model of the hip could help guide both surgical intervention and implant design, leading to improved outcomes for the thousands of hip surgeries in Canada each year.

REFERENCES