INTRODUCTION:
Previously, Komistek et al have demonstrated anomalous behaviors in total joints such as separation (sliding) in THAs and condylar lift-off in TKAs. These cases result in reduced contact area, increased contact pressure, polyethylene wear and could induce prosthetic loosening and joint instability. However, there is no known research done on correlating these conditions with acoustic data. This study deals with the development of a new method to diagnose such conditions using sound and frequency data. The objective of this study was to determine and compare the in vivo, 3D kinematics and sound for subjects having both a Hi-Flex Posterior Stabilized (PS) Mobile Bearing (MB) TKA and a contralateral non implanted knee, compared to other subjects having a normal knee.

METHODS:
Ten subjects having a Hi-Flex PS MB TKA and a contralateral non implanted knee and five normal subjects were analyzed under in vivo, weight-bearing conditions using video fluoroscopy and a sound sensor while performing four different activities. (1) deep knee bend to maximum flexion, (2) gait, (3) stair climb and (4) chair rise and sit. Three piezoelectric tri-axial accelerometers were attached to the femoral epicondyle, tibial tuberosity and the patella respectively. The sensor detects frequencies that are propagated through the tibio-femoral interaction. The signal from the accelerometers was then transferred to a signal conditioner for signal amplification. A data acquisition system was then connected to receive the amplified signal from the signal conditioner and transfer it to a laptop for storage. A sampling rate of 10500Hz was used and frequencies up to 5000Hz were recorded. The signal was then converted to audible sound (Figure 1).

Also, 3D tibio-femoral kinematics of the knee was determined, for the four activities with the help of a previously published 2D-to-3D registration technique (Figure 2 and 3).

RESULTS:
On average the subjects achieved more flexion with their TKA than with their contralateral knee and consequently experienced significantly higher ROM for their implanted knee. However, both of these groups achieved lower ROM than the normal knees. Significant differences were seen in the AP position of the tibiofemoral contact point. The contact point of the medial condyle for the TKA knee was significantly more posterior at 0° and 30° and remained more posterior than the same condyle of the contralateral throughout flexion. Posterior femoral rollback was seen in all groups, with the normal knee achieving significantly higher posterior femoral rollback when compared to the contralateral and TKA knees.

Audible signals were observed for all three groups of knees. However, subjects with a TKA experienced higher frequencies than the normal and contralateral knees. Also, 3D kinematics was correlated to conditions arising in TKAs such as condylar lift-off. Possibility of correlating bearing mobility, to the propagating frequencies, is currently being investigated.

The frequency analysis (Figure 3) revealed that specific frequencies for all groups were within the same range, but the most dominant frequency for each varied. This may be related to the variable interaction surfaces leading to different dominant frequencies which were excited at magnitudes related to the type of material being impacted (polyethylene/meniscus).

DISCUSSION:
This was the first study to correlate in vivo kinematics to in vivo sounds in the knee. The sounds that were detected correlated well to in vivo motions, especially abnormal kinematic patterns. The ultimate aim of this study is to create a stand alone tool (based only on sound data) that could be used as a diagnostic tool to determine total joint conditions and reduce the dependence on radiation techniques.