INTRODUCTION:
Initial implant stability is an important factor for the success of cement-less total knee arthroplasty. D’Lima et al has reported in-vivo forces using an instrumented tibial tray. Recently Heinlein et al also reported in-vivo instrumented all tibial loading components including moment elements. To date, the effects of the moments to the initial stability of common tibial anchoring designs were not well studied. For the typical stem-keel and peg design, we hypothesized that a stem-keel design will resist flex moment than a peg design more effectively. The purpose of this study was to investigate the tibial bone-implant micromotion under separated pure torque moments for a keeled and 3 peg tibial designs.

METHODS:
Three dimensional Finite Element Analysis (FEA) included the models of tibia bone and tibial tray implants. The left tibia was obtained from CT scan (Virtual bone data base, Munich University, Germany). The bone model was then converted to CAD files (Pro/Engineer Wildfire v2.0 Parametric Technology Corporation, Waltham, MA). Two corresponding generic tibial tray implants including the 33mm long tri-flange stem-keel design (Figure 1) and 12mm out side diameter (OD) X 16mm long 3 peg design (Figure 2) were generated in 3-D models in Pro/Engineer. The tibial implants were assembled in exact same orientation to two identical tibia bones with proximal plateau being virtually cut. The tibia bones were then prepared line to line interference fit for the stem-keel and pegs. The distal tibia bones were cut to 100mm from proximal plateau. The two assembled models were subsequently imported into ANSYS Workbench v11.0 (ANSYS Inc., Canonsburg, PA). For comparative purpose only, uniform isotropic and linear elastic cancellous bone properties were assumed. The Young’s modulus (E) for cancellous bone was 570 MPa and the Poisson’s ratio (v) was 0.3. Both tibial trays were 6AL4VELI titanium alloy with 1.5mm thick flat bone contacting layer of CP titanium foam. The E for the titanium alloy was 95.6GPa and 5GPa for titanium foam. Both materials had v of 0.34. The interfacial connections were: frictional connections with coefficient of friction =0.4 were assumed for bone to stem-keel, pegs and titanium foam layer; bonding connections were constructed between titanium foams to solid trays and solid anchors. The moment loadings were applied to the local coordinate system located at the center of the tray. The models were based on the highest values reported by Heinlein et al as the stair descending activity. The flexion moment M_A-P=24.920 N-M. The body weight was assumed as 875N. The pure moment loading which includes the compressive force. The pure moment loadings were M_E-R and M_M-L. The results were verified by the physical testing of an actual keel tray implanted in the open cell saw bone (12.5 pcf foam, , E = 47.5MPa, v=0.3, Saw Bones, Vashon, WA) under pure rotational moment M_E-R. The pure moment loadings were M_A-P and M_M-L. The results were verified by the physical testing of an actual keel tray implanted in the open cell saw bone (12.5 pcf foam, E = 47.5MPa, v=0.3, Saw Bones, Vashon, WA) under pure rotational moment M_E-R. The pure moment loadings were M_A-P and M_M-L. The results were verified by the physical testing of an actual keel tray implanted in the open cell saw bone (12.5 pcf foam, E = 47.5MPa, v=0.3, Saw Bones, Vashon, WA) under pure rotational moment M_E-R. The pure moment loadings were M_A-P and M_M-L.

RESULTS:
The micromotion was obtained from the sliding distance between contacting surfaces. The maximum micromotion locations due to primary loadings of M_A-P and M_M-L are shown in figure 4 and 5. The maximum micromotion for M_A-P occurred in anterior spine of stem-keel and anterior peg. For M_M-L, the maximum micromotion located at the lateral fin of the stem-keel and lateral peg respectively. The highest micromotion was under pure valgus-varus moment and the lowest was in external rotation for both designs. The stem-keel design had 46.9%, 44.3% and 21.6% reductions in micromotion from 3 peg design under valgus-varus, rotational and flexion moments respectively (Figure 6) The saw bone FEA result of the maximum micromotion under pure external rotation was 0.276 mm which was higher than 0.036mm for the bone. The physical verification test revealed the average micromotion was 0.343mm (0.40mm, 0.38mm and 0.25mm) SD=0.0845. Both results are shown in Figure 7 and 8.

DISCUSSION:
The highest micromotion reduction occurred in valgus-varus moment for keel design. This finding did not agree with the hypothesis. The length and grooves of tri-flange keel may have contributed to the higher resistance to the moments especially to the valgus-varus moment. In the pure moment loading condition and without the compressive force, the implant-bone micromotion was magnified. That was purposely used in the study to identify the influence of each moment. These findings should not be used to predict actual micromotion under total anatomical loading which includes the compressive force. The pure moment however is often applied intra-operatively to access tibial implant stability and it is an exaggerated worse case scenario to which these finding are relevant. The modulus of bone influenced the micromotion as the lower modulus of saw bone resulted in higher micromotion than cancellous bone.