INTRODUCTION:
With the increased use of minimally invasive surgical (MIS) techniques there is a need for implant designs that allow for insertion with a reduction in soft tissue damage. The majority of tibial tray designs incorporate a distal post with a modular taper that allows for the use of intramedullary stems. However, during MIS surgeries the soft tissues must be stretched to allow clearance for the integrated stem during tray insertion into the tibia. Lower clearance tibial trays have been introduced to alleviate this need and to allow insertion with a minimum of tissue damage. One potential drawback from the reduction of distal material is a possible decrease in the stability of the tibial tray when subjected to torsional or offset axial loading. The objective of this study was to examine the effects of reducing the distal stem length on the stability of tibial trays.

METHODS:
The torsional resistance and axial stability of a standard stemmed tibial tray and lower profile MIS tray were compared using finite element analysis (FEA) and mechanical testing. Size 5 GENESIS II tibial trays and GENESIS II MIS trays (Smith & Nephew, Memphis, TN), were used for the comparison (Figure 1). The MIS tray has a similar fin geometry as the standard tray, but requires only 20 mm of clearance compared to 50 mm for the standard tray.

An FEA was first performed on the two designs under cemented conditions to simulate the torsional resistance and the anterior tray lift-off under a 2002 N posterior axial load (60% medial and 40% lateral). The model was an idealized situation where optimal contact at the mating surfaces was obtained. The contact conditions do not replicate the mechanical test, but should show the effect of the reduced fin surface area seen on the MIS tray.

Mechanical testing under torsional and axial loading was performed for both non-fixed and cemented conditions. Although both trays are indicated for cemented use only, the non-fixed condition will represent a worst-case condition where the tray has no cement fixation to isolate the effect of the geometry change alone. Third generation composite tibiae (Pacific Research, WA) were used to simulate the implantation conditions. Testing was performed on the standard tibial tray for comparison to the MIS tray design (n=3 of each). A rotation of ±2° was applied to the tibial tray to determine torsional stability, and the resulting torque was recorded. The torque range generated from the 4° of total rotation was compared for the standard and MIS tibial trays. For axial testing, a displacement transducer was placed at the anterior edge of the tibial tray, and an increasing load up to 2002 N was applied to the posterior edge of the tibial tray at both condyles. The ratio of the anterior liftoff to applied load was used for comparison.

Statistical analyses were performed using Student’s t-tests to compare the torsional and axial loading results for the two tray designs.

RESULTS:
The FEA showed that the torsional resistance for the MIS tray in the cemented condition was 6% lower compared to the standard tray. The results of the FEA were similar to the mechanical testing, which found little difference in the torsional stability with the reduction in stem length and fin area in both the cemented and non-fixed conditions (Figure 2). The FEA simulating the anterior displacement for the cemented condition showed little numerical difference, 0.018 mm and 0.025 mm, for the MIS and standard trays, respectively. These results were similar to the results found during mechanical testing (Figure 3). Under non-fixed conditions, a difference in the averages may be evident but any differences between the two tray designs were within the error of the test.

No statistically significant differences were found between the standard tray and MIS tray for all test conditions at p=0.05.

DISCUSSION:
Under cemented conditions, no statistically significant differences were found between the torsional and axial stability of the two tray designs. The lack of difference under torsional loading is likely due to the preservation of over 80% of the fin geometry which provides the majority of the torsional resistance. Under axial loading, the additional length of stem for the standard tibial tray does not contribute to the axial stability of because it is either unsupported within the intramedullary canal or supported by soft trabecular bone.

Based on the results of FEA and mechanical testing, under conditions of good cement fixation reducing the distal stem length by 30 mm does not appear to decrease the torsional or axial stability in the tibial tray design that was tested.