INTRODUCTION:
With the current estimated incidence of all malleolar fractures being between 107 and 187 per 100,000 person-years, orthopaedic surgeons frequently encounter fractures of the medial malleolus. Such injuries are commonly treated with open reduction and internal fixation with good results. However, there currently exists no consensus as to what constitutes biomechanically optimal internal fixation. Two fixation techniques using cancellous screws are commonly cited in the literature. The first recommends placement of the cancellous screws with the threads positioned at or just proximal to the physeal scar. The second recommends placement of the cancellous screws with the threads placed well proximal to the physeal scar, without engaging the lateral cortex. Both recommendations suggest that their technique places the threads of the screw within better bone for better fixation but no scientific evidence in the literature supports either recommendation at this time. One of the dominant factors affecting pullout strength of cancellous screws is the screw placement, as bone density is more variable in trabecular bone. The objective of this study is to analyze the effect of thread placement on screw pullout strength and stiffness. We hypothesized that a longer screw, with the threads placed well proximal to the physeal scar without engaging the lateral cortex of the tibia, would have significant higher pullout strength than a shorter screw, which was placed at or immediately proximal to the physeal scar of the tibia.

METHODS:
Specimen Preparation: Eight (n=8) pairs of fresh-frozen cadaveric distal tibiae were retrieved for this study. The matched pairs were implanted with a 4.0mm stainless steel cancellous screw (Synthes, Paoli, PA) of different length. For Group 1, a 30mm partially threaded screw with long threads (thread length 15mm) was used. For Group 2, a 45mm partially threaded screw with short threads (thread length 15mm) was used. Radiographs of the distal tibia were used to determine the orientation and depth of the screw insertion, and the insertion orientation was marked on the specimen using permanent marker. A pilot hole was first created using a table drill to ensure the drill axis aligned with the desired orientation. The appropriate screw was then inserted by hand to the pre-determined depth.

Pullout Test: In-line pullout test was performed using a servo-hydraulic material testing system (Model 809, MTS Systems, Eden Prairie, MN). A special jig was applied to secure the screw head to the MTS crosshead, and the distal tibia was embedded in dental cement and secured to the base of the MTS. This procedure ensured the pullout force aligned with the screw axis. Pullout tests were performed under displacement-control at a rate of 0.1 mm/sec until a drop of force was detected or a maximum displacement of 2.0 mm was reached. The maximum tensile force and maximum displacement at the point of failure and linear region stiffness were determined from the load-displacement curve.

Radiographic Evaluation: Following the pullout test, each pair of the distal tibia was kept frozen in a −20 °C freezer. Frozen distal tibia was sectioned into 6 mm thick slabs using a band saw. Each slab contained the screw hole in the middle and with the two cutting planes parallel to the screw axis. Transverse radiographs of the bone slabs along with a standard radiopaque step wedge were taken using a high resolution radiographic unit (Faxitron, McMinnville, OR) and high resolution film. Grey-scale images of these radiographs were obtained by a Leica digital camera (Figure 1). Relative density of the cancellous bone around the screw hole were measured by averaging the pixel density along lines drawn parallel to the screw axis and within one radius on either side of the screw hole, using Image Pro software (Cybernetics, Inc., Silver Spring, MD). The same technique was also applied to obtain the mean pixel density of the step wedge image taken with each slab. The difference in wedge density between slabs was used as a correction factor to normalize the relative bone density among slabs.

Statistical Analysis: Paired Student’s t-tests were performed to compare the differences in pullout strength and stiffness between the two screw groups. Least-square regression analysis was carried out to test the effect of cancellous density near the screw anchoring sites on pullout strength and stiffness for each screw group.

RESULTS:
Results from one pair of the specimens were removed from the analysis as an outlier due to its extreme high values in pullout strength and stiffness. Therefore seven pairs of specimens (4 male, 3 female; age range 55-85yrs) were included in all analysis. The mean pullout strength of the 45mm screw was 225.7±167 N, 48% stronger when compared with 152.1±113 N of the 30mm screw (p=0.04). The initial stiffness measured from the linear region of the pullout load-displacement curves showed significantly greater (47%) stiffness from the longer screw (307.4±195 N/mm over 209.4±183 N/mm, p=0.005). In radiographic evaluation, large variation in the density measure was observed from the seven pairs of specimens (mean 67.8, range 43.8 to 89.7), though the density between each matched pair was comparable. Regression analysis showed moderate association between bone density and mechanical variables from the pullout tests (correlation coefficient range 0.67 to 0.79).

DISCUSSION:
Medial malleolar fractures, whether alone or as part of a bimalleolar or trimalleolar ankle fracture, are among the most common fractures encountered. While nonoperative treatment may be successful for completely nondisplaced, isolated medial malleolar fractures, most medial malleolar injuries will require operative fixation. The aim of our study is to assess the pullout strength of partially threaded 4.0mm cancellous screws placed in two distinct anatomic locations within the distal tibia. We believe that finding the anatomic area that exhibits greater pullout strength will help guide the orthopaedic surgeon to optimal placement of fixation for medial malleolar fractures. Based on our findings, treatment of medial malleolar fractures with partially threaded cancellous screw fixation would benefit from screw threads placed well proximal to the physeal scar, closer towards the lateral cortex. Screws placed more proximal to the physeal scar exhibited greater pullout strength and pullout stiffness. This relationship was exhibited in both high-density and low-density bone.

Limitations of this study include small sample size (n=7). Secondly, in order to keep thread length equivalent between the two groups, only 30mm long thread and 45mm short thread screws could be used, since this yielded equivalent thread lengths (15mm) across all specimens. While this provided reasonable placement of the fixation in the anatomic locations of interest, normal anatomic and specimen size variability make perfect, direct comparisons between specimens more difficult.

SIGNIFICANCE:
The data generated from this cadaveric study may help guide surgeons to optimal fixation of medial malleolar fractures. Further testing may provide specific guidelines regarding optimal areas of bone mineral density in both low- and high-density bone.