Introduction: The maintenance of sagittal balance following anterior cervical reconstruction is essential in obtaining a good outcome. Although endplate fracture can result in traumatic loss of anterior column height, generally the loss of anterior height occurs as a result of fatigue failure of the endplate. This results in a loss of sagittal balance and recurrence of foraminal stenosis. A significant amount of published literature has been directed at the graft endplate interface and the risk of subsidence from endplate fracture. The regional and biomechanical variations of the endplate are important and well understood. It appears that the posterior and the lateral aspect of the cervical endplate are thicker and stronger than the anterior and the middle aspects of the endplate. The quality of the bone is an important factor and has been shown to correlate with the strength of the vertebral endplate. However, the fatigue characteristics of the strut graft construct has not been well defined. The purpose of this study was to examine the biomechanics of three typical anterior strut graft constructs to see if the fatigue characteristics were dependent upon bone density or the type of graft construct.

Materials and Methods: Five cervical specimens (average age of 80±5 years, 2 female, 3 male) were harvested en bloc. Scanning was performed on a Stratec XCT-2000 pQCT scanner for determination of trabecular bone content (C3-T1). Transaxial slices of 2.3mm thickness were collected at each level and the trabecular bone content was measured by selecting the vertebral body as the region of interest and removing the cortical edge in the image using a thresholding and edge detection algorithm. The average trabecular bone density was determined by averaging the measured densities between the endplates of each vertebra (3–4 slices). Levels C3-T1 were then dissected and care was taken to preserve the endplates of each vertebra. Each vertebra was partially embedded in a body filler mold to level the superior endplate surface for biomechanical testing of the endplate. Three clinically relevant strut graft constructs were examined: fibular allograft, titanium mesh cage packed with allograft chips, and trabecular metal. Each type of graft construct was tested at a mid (C3-C5) and low (C6-T1) level on all cervical spines. Each graft construct was ramp loaded in compression (range -25 to -250N) for 5 cycles prior to and following 10k sinuousoidal cycles of fatigue loading (2 Hz) for determination of construct stiffness and graft subsidence. The pre- and post-fatigue stiffness was calculated by averaging the stiffness (load range from 100-250N) of cycles 3-5 from the ramp loaded phases of testing. In addition, the pre- and post-fatigue peak displacement for each specimen was determined by the peak displacement at 250N of cycle 5. Overall graft subsidence was measured from the fatigue loading. Regression analyses were performed to examine relationships between the strut graft construct parameters (stiffness, peak displacement, and subsidence) and the trabecular bone density. Two-way ANCOVAS with time (pre, post) and graft type as factors were performed with density as the covariate to examine differences in stiffness, peak displacement, and subsidence. Post-hoc tests were performed when the overall model was significant. The level of significance was set to p<0.05 for all tests.

Results: The average apparent bone density of individual vertebral bodies was 230±45 mg/cm³ (range: 167–335 mg/cm³); there was no significant relationship between trabecular bone density and the strut graft construct parameters. The pre and post fatigue stiffnesses (N/mm) were 1040±230 in the fibular allograft group, 1450±140 in the titanium mesh group, and 1150±180 and 1690±170 in the trabecular metal group (Figure 1); each construct was significantly stiffer following the cyclic testing (p<0.001). There was a significant difference between the trabecular metal and titanium mesh groups in stiffness prior to the fatigue testing (p=0.027). Following fatigue, a significant difference was noted in the post-fatigue stiffness between the trabecular metal and the titanium mesh group (p=0.002). There was also a significant difference noted between the allograft and the titanium mesh group (p<0.001). The pre and post fatigue peak displacement of the constructs were 0.8±0.3mm and 1.3±0.5mm in the allograft group, 1.0±0.4mm and 1.7±0.7mm in the mesh group, and 0.6±0.3mm and 0.9±0.5mm in the trabecular metal group. Overall, there was a significant difference in the post-fatigue peak displacement as compared to the pre-fatigue peak displacement (p<0.001). There was a significant difference noted in the pre-fatigue peak displacement between the trabecular metal and the titanium mesh cage (p=0.04) and in the post-fatigue peak displacement between the trabecular metal and the titanium mesh cage (p=0.008). A difference was noted between the three constructs in the amount of overall subsidence from the cyclic loading with the trabecular metal construct having the lowest amount of subsidence.

Discussion: Previous studies have shown a correlation between bone density and the structural properties of the vertebral endplate as well as the failure load of a construct. In this current fatigue study, there was no correlation between bone density and the biomechanical parameters investigated. Nondestructive cyclic loading of a cervical strut graft construct resulted in a stiffer construct independent of the type of the interbody implant used. In addition, the trabecular metal and the allograft constructs were stiffer than the titanium mesh construct. The amount of subsidence during fatigue loading was dependent on the interbody construct. The lowest amount of settling was noted with the trabecular metal construct followed by the allograft construct and the largest amount of settling was seen with the mesh construct. The trabecular metal construct appears to have the lowest amount of settling and this effect can be advantageous in vivo.