Five fresh human cadaveric cervical spines (C2-T1) were harvested and radiographed to exclude those with osteopenia. The spines were mounted in a programmable testing apparatus to determine their biomechanical behavior. Five spines were tested in four sequential conditions. They included harvested (H), C4-C6 corpectomy (C), strut-grafted (SG), and SG with anterior cervical plate (SGAP). An existing flexion/extension spine testing protocol [1] was modified to include strut-graft loading mechanics. Following harvested and corpectomy testing, a multi-axis force-sensing strut-graft (MAFSSG) was inserted into the corpectomized region. The shape and size of the multi-axis FSSG were similar to a typical bone strut-graft: 12mm diameter x 0.5 mm thick stainless steel tube adjustable in length from 35 to 100mm. The transducer measured axial tension / compression (+/- 225N), flexion / extension and lateral bending moments (5.75Nm), and axial torsion (105Nm); channel resolution was 0.5% full scale. After insertion into the corpectomy, the MAFSSG was adjusted in length to register a pre-load of 20N. An Orion anterior cervical plate (Sofamor Danek Group) was attached from C3 to C7. Output from the MAFSSG was normalized to the applied plus pre-load and compared at the end limits of motion. Strut-graft load data with or without the anterior cervical plate were analyzed using paired t-tests (p<0.05). Motion data of the individual spinal segments, operated region, and total construct were measured with an optical tracking system and combined with the loading data to calculate stiffness properties. Motion data was normalized to the harvested spine and compared using paired t-tests (p<0.05). Additional measurements included the loads and moments applied to and transferred through the spine.

RESULTS: Typical local (C3-C7) versus global (C2-T1) motion response curves are shown in figure 1. Values of the normalized local motion are shown in figure 2. The motion was within a range seen clinically with various cervical orthoses [3]. Local motion was significantly less for the SGAP construct (p<0.05). Normalized MAFSSG compressive loads are shown in figure 3. Flexion of the SG spine loaded the MAFSSG; extension motion unloaded the SGAP. Attachment of an Orion plate increased the MAFSSG load. Flexion of the plated spine unloaded the MAFSSG; extension motion loaded the MAFSSG. The MAFSSG loads were significantly higher during flexion of the SG spine than the SGAP spine (p<0.05) and lower in extension testing (p>0.05). At similar degrees of flexion and extension, greater compressive loads were transferred through the strut graft during extension of the SGAP spine than flexion of the non-plated spine (p<0.05). Lastly, the bending and multiple moments transferred through the MAFSSG were minimal (i.e., less than 15% of applied load).

DISCUSSION: Clinical experience has shown that anterior cervical plating does not prevent construct failure in multi-level cervical corpectomy [2]. A significant factor underlying construct failure in this setting is pistoning of the strut-graft. Intuitively (and as the study confirms), flexion of a strut-grafted cervical spine increases the axial loads on the graft, which can lead to pistoning. Application of an anterior cervical plate unloads the strut-graft in flexion. Extension of the plated construct loads the strut-graft and these loads exceed those seen with similar degrees of flexion of the strut-grafted spine. For either of these excessive loading cases, the level of load (and compressive stress) transferred through the strut-graft should not exceed the compressive strength of the vertebral end-plates to prevent end plate fracture or pistoning of the strut-graft. We conclude that anterior cervical plating reverses the loads that are transferred through a multi-level cervical strut-graft and may promote pistoning of the grafts in extension.