INTRODUCTION:
Degeneration of the cervical intervertebral disc is the underlying cause for many patients suffering from neck and upper extremity pain. For patients who fail conservative therapy, the current gold-standard for treatment of cervical pathology is an anterior cervical disectomy and fusion (ACDF). Using a similar surgical approach, cervical total disc replacement has recently gained popularity. Open ACDF's and cervical disc replacements are common, but next generation implants and less invasive surgical techniques are predicated on a comprehensive characterization of cervical endplate morphology.

To date, cervical endplate morphometry has not been described in the literature in detail. Furthermore, age-related and gender-dependent differences in cervical morphometry have not been characterized.

The purpose of this research was to measure cervical endplate morphometry in both men and women across three decades of life and characterize age, gender, and level-dependent trends.

METHODS:
Bony skeletal specimens were utilized from the Hamann-Todd Collection of the Cleveland Museum of Natural History. Cervical vertebrae from 12 male and 12 female skeletons were analyzed. Specimens were selected from age groups ranging from 30 to 60 years old. C4, 4th decade 44.4 years, mean female 44.3 years. A FaroArm 3D laser scanner (Faro Technologies; Lake Mary, FL) equipped with InnovMetric Software (Polyworks Inc., Quebec, CA) was used to scan specimens with a resolution of 0.015 mm. Detailed surface scans of C4 through C7 vertebrae were used to generate three-dimensional point cloud files for each specimen. High resolution photographs were also taken of each specimen.

Files were processed from the raw 3D point cloud data to a polygonal mesh using InnovMetric. After optimizing the mesh and resolving inclinations and redundancies, endplate STL files were generated and exported to Geomagic Studio 12 (Geomagic, Research Triangle Park, NC). Meshes were translated into surfaces after filling inclusions and holes and reducing spikes and noise. Curves were created to transition the meshes to non-uniform rational basis spline (NURBS) surfaces. Files were then exported in IGES format for further processing in SolidWorks (Solidworks Corp, Concord, MA). From solid models, the lateral and anterior/posterior margins of the endplates were identified and measured using the dimensioning tools in the software. Lateral margins were defined at the transition of the curve created by the uncinate processes and the endplate. Anterior and posterior endplate margins were selected from mid-sagittal sections of each specimen. AP and lateral dimensions of each superior and inferior endplate were measured using these points.

Mid-sagittal and para-sagittal planes as well as mid-coronal and anterior and posterior planes were created in the solid model to measure endplate curvature (Figure 1). The radius of curvature, center of curvature, and arc length were calculated for each plane of each endplate.

Endplate “roughness” was also measured from cut planes. Roughness is an indicator of the irregularity of the surface of the endplate and was defined as the difference between the highest and lowest points on the surface of each endplate.

Data were collected for each specimen and pooled with other specimens to determine the mean values at each level of the cervical spine (C4-C7) for each decade of life (30’s, 40’s, 50’s) for each gender.

To determine differences between gender, males and females were compared by spinal level within each decade using independent mean t-tests. (Male, C6, 4th decade compared to female, C6, 4th decade.) To determine age-dependent differences, specimens within each gender were grouped by spine level and compared across age groups using an ANOVA and Games-Howell post-hoc testing. (Male, C6, 4th decade compared to male, C6, 5th decade, compared to male, C6, 6th decade.) Superior and inferior endplate lateral width, anterior/posterior depth, radius of curvature, and roughness were compared across all level-age-gender combinations.

RESULTS:
In all specimens, the shape and morphology of the superior endplate was significantly different from the inferior endplate (Figure 2). Preliminary analysis indicates an increasing width with descending level for all ages and genders and larger depth for C6 and C7 relative to C4 and C5 for all ages and genders. Width and depth of the endplate do not change with increasing age. Endplate curvature is highly variable even within level-gender-age groups.

DISCUSSION:
Using our technique, the solid models of all C4 to C7 specimens from the 24 skeletons allowed detailed quantitative characterization of the endplates.

Gross analysis revealed that no 4th decade specimens had signs of osteophyte formation, but all specimens in the 6th decade had at least some, with many exhibiting significant osteophytosis. These changes were the primary source of differences in morphology associated with aging. Qualitatively, there appeared to be substantial differences in endplate morphology primarily at the periphery of the vertebrae and thus did not change endplate dimensions.

SIGNIFICANCE:
Results from this study indicate that there are significant differences in endplate shape and size across spinal level, age, and gender. There may be advantages to developing age, gender and level specific future implants and surgical instruments.

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