INTRODUCTION:
Disc degeneration is a natural process and is widely prevalent. The level of disc degeneration and the type of treatment varies from person to person. Fusion is a commonly chosen treatment option. However clinical and biomechanical studies have shown that spinal levels adjacent to a fusion experience increased motion and higher stress which may lead to adjacent-segment disease [1].

Cervical disc arthroplasty achieves similar decompression of the neural elements, but preserves the motion at the operated level and may potentially decrease the occurrence of adjacent segment degeneration.

METHODS:
In this study, a validated specimen-specific 3D finite element model of the cervical spine (C2-T1) was used [2] (Figure 1). The intact model was subjected to pure moments in flexion-extension, lateral bending, and axial rotation moments up to ±2.0 Nm. The intact model was modified to simulate degeneration at the C5-C6 level. Thereafter, the degenerated model was modified to simulate fusion and as well as two arthroplasty procedures (i.e., the Bryan and Prestige LP cervical discs) at the C5-C6 level.

Degenerative Model: A moderately degenerated disc was simulated at the C5-C6 level by removing the hydrostatic capabilities of the nucleus and by making the annulus and nucleus stiffer than the normal disc [3].

Fused C5-C6 disc: The fusion was simulated by changing the properties of the C5-C6 intervertebral disc to that of bone (i.e., E = 5 GPa).

Total Disc Replacement (TDR):
Bryan Cervical Disc Model: The Bryan cervical disc contains a polycarbonate polyurethane nucleus which articulates with a titanium shell on the top and bottom. A polyurethane sheath surrounds the nucleus and is attached to each shell using titanium wires. An adequate sized (16mm diameter) disc was modeled using hexahedral elements. The polyurethane shell and titanium wires were not modeled since they are functionally inert. The titanium shells and polyurethane nucleus were meshed using hexahedral elements [4]. The interaction between the implant and the vertebral bodies were considered TIED, while the contact between the shells and the nucleus was modeled as Finite Sliding with coefficient of friction of 0.1. A Young’s Modulus (Poisson’s Ratio) of 110GPa (0.3) and 30MPa (0.45) were assigned to the shells and the nucleus, respectively.

Prestige LP Disc Model: The Prestige LP is a titanium ceramic composite device with two articulating components (ball on top & trough on the bottom) that attach to the vertebral bodies. Both components were meshed with hexahedral elements using IA-FEMesh [4]. The interaction between the disc and the body was modeled as TIED and between the ball and trough was modeled as Finite Sliding with a coefficient of friction of 0.1. Both the components were assigned an elastic modulus of 110GPa and Poisson’s Ratio of 0.3.

TDR Simulation: The degenerated model was modified to simulate a TDR at the C5-C6 level (Figure 1). First the anterior longitudinal ligament was removed at that level. Then the nucleus and anterior and posterior parts of the annulus were removed creating space for the disc. Some part of the lateral annulus and the uncinate processes were left intact. The endplates were prepared as per the Bryan and Prestige LP surgical technique manuals. The milling and cutting operations were simulated using an in house Surgical Simulation Suite [5].

Each model was analyzed again in flexion-extension, lateral bending, and axial rotation by increasing the moment until the motion matched that of the intact C2-T1 motion (Hybrid Control). The analysis was performed using ABAQUS 6.9.

RESULTS:

Figure 2: Percent change in Flexion-Extension motion at the operative level and as well as the adjacent level, above and below.

DISCUSSION:
In this study, we compared single level arthroplasty and fusion using a detailed 3D Finite Element model of the cervical spine (C2-T1). Rather than simulating an arthroplasty or fusion on an intact healthy model, it seemed clinically relevant to simulate a degenerated disc. The FE model predictions show similar results for arthroplasty with both Bryan and Prestige LP discs. Preservation of motion at the implanted level and a decrease in motion at the adjacent levels whereas fusion resulted in an increase at the adjacent levels and decrease at the fused level. Similar trends were observed in Lateral Bending and Axial Rotation.

SIGNIFICANCE:
There is great optimism that cervical arthroplasty will improve the results achieved with fusion and this study definitely corroborates it. To our knowledge, this is the first FE study involving Prestige LP.

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REFERENCES: