INTRODUCTION:
Cervical fusion is commonly performed for various spinal diagnoses. Among other factors, success is dependent on achieving solid bony fusion. In patients continuing neck pain, pseudarthrosis is often suspected. While open surgical exploration is considered the “gold standard”; it is not a practical method of routine assessment. Plain radiographs are the most commonly utilized method of serial noninvasive assessment of cervical fusion healing. As static radiographs are often inconclusive, dynamic flexion-extension (F-E) views (i.e. lateral radiographs taken in full flexion and extension) have been advocated to increase accuracy.

The utility of F-E views is based on the presumption that a solid fusion would allow little sagittal motion, while a pseudarthrosis would permit a greater amount. Accordingly, cut-off criteria have been purported that reflect the maximal amount of motion thought to be detectable with a solid fusion. Conversely, greater motion is generally believed to be diagnostic for pseudarthrosis.

Despite its widespread use, there remains little agreement of the optimal F-E criteria. Authors have published recommendations that range from 0 to 20 degrees. Though estimates based on clinical experience, these values have not been derived by scientific methods. Furthermore, these recommendations do not distinguish between different fusion locations, techniques, or degrees of completeness.

In an extensive review of the literature, the authors could find no experimental validation of any criteria concerning residual sagittal (F-E) motion after solid cervical fusion. It was the authors’ objective to characterize the amount of angular sagittal motion permitted across various kinds of simulated cervical fusion, hypothesizing that the location, technique, and completeness of fusion would have an effect.

METHODS:
A 3-dimensional, nonlinear, experimentally validated C4-C6 finite element model was used. To simulate anterior discectomy and interbody fusion (IBF) at the C5-6 level, anterior annulus, nucleus pulposus, and anterior longitudinal ligament were removed. Solid bridging bone graft, consisting of a cancellous core with an outer cortical shell of 1.5 mm was used to simulate the interbody fusion mass. Varying levels of “completeness” (percentage surface area of the disc space) were simulated to represent clinically representative degrees of fusion. These included solid bridging bone in the entire (100%) disc space or the anterior or posterior 75%, 50%, and 25%, simulating solid but “incomplete” fusion.

Posterior facet fusion (FF) was represented by solid bridging cancellous bone between the articular surfaces of the joint. Both unilateral (UL) and bilateral (BL) FF were tested. In this model, facet capsular ligaments at C5C6 were removed, as they would have during surgery.

In the intact model as well as each fusion scenario, the model was pre-loaded with 75 N of axial compression to simulate the weight of a human head. 2 Nm sagittal moments were used to simulate physiologic forces needed flex and extend the cervical spine.

RESULTS:
IBF: The intact model had 15.5 degrees F-E motion. 100 % IBF had only 2.5 degrees of motion. With 75, 50, and 25% anterior IBF, 3.3, 5.3, and 6.6 degrees was allowed, respectively. With the 75, 50, and 25% posterior IBF, 3.5, 6.6, 10.8 degrees of F-E motion was detected, respectively.

FF: BL FF resulted in 2.5 degrees of sagittal motion. Left UL FF resulted in 3.4 degrees of motion. Right UL FF resulted in 4.0 degrees of motion.

DISCUSSION:
The more “complete” the fusion, the less sagittal angular motion permitted across the segment. The data also suggest that the location of the cervical IBF mass may have an influence on the amount of motion permitted, with a solid but incomplete anterior fusion mass allowing considerably less motion than a solid but incomplete posterior IBF mass. Interestingly, a solid BL FF resulted in equivalent motion as a solid IBF. To the authors’ knowledge, these are the first data to attempt to characterize the amount of sagittal angular motion in a simulated healed cervical fusion.