ABSTRACT INTRODUCTION:
Anterior lumbar interbody fusion (ALIF) using threaded cages has been shown to reduce segmental motion and restore the disc space. The effectiveness of these stand-alone cages in restoration and maintenance of intervertebral foramen has received little attention. Foraminal height reduces an average of 6.5 mm following disc removal, and interbody cages may indirectly increase and stabilize foraminal dimensions by restoring disc height in patients with degenerative disc disease. A few studies have addressed the influence of disc space distraction on the dimensions of the neuroforamen, either with interbody cages1,2, or posterior instrumentation3. To our knowledge there has been no prior investigation of foraminal space changes following implantation of tapered cages, which exhibit distinctly different geometry from the cylindrical cages. Also, the effectiveness of ALIF cages in maintaining foraminal space under dynamic loading conditions has received little attention. The objectives of this study were to investigate the effects of anterior implantation of threaded cylindrical and tapered interbody cages on: 1) morphology of the lumbar neuroforamen and 2) maintenance of foraminal dimensions under dynamic loading in flexion, extension, and lateral bending.

METHODS:
Sixteen fresh lumbar spine specimens (L2-L5) from bovine calf were obtained for the study. The L5 vertebra of the specimen was potted in dental cement with a loading ring mounted to the L2 vertebral body. The specimens were randomly assigned to two ALIF groups: one received two tapered lumbar cages (LT-cages, MSD, Memphis, TN) and the other received two cylindrical lumbar cages (Ray TFC/Unite system, Stryker Spine, Allendale, NJ). The techniques of cage insertion followed the recommendations of the manufacturers, and consisted of anterior discectomy, sequential annulus distraction using sized distraction spacers, followed by reaming, tapping, and insertion of the cages. Similar sized implants were used in all tested specimens (LT-cages: 14-17.5 mm by 21 mm; Ray TFC/Unified: 14 mm by 21 mm).

Pure moment of 8.5 Nm was applied to the spine in four directions: flexion, extension, and left and right lateral bending. Intervertebral motion of the ALIF segment (L3-L4) was recorded and analyzed with a motion analysis system. To measure the intervertebral foramen space, instant molding compound was carefully molded into the intervertebral foraminal space on both sides, and allowed to cure for one minute. The narrowest cross-section along the mold tangential to the neuroforamen passage was identified, and the mold was sectioned through this plane. A cross-sectional imprint of the foramen in this plane was created with an instant mold and placed through a digital imaging system. Two sets of bilateral foraminal molds were obtained when the spine was in neutral unloaded position, one from the intact spine and one following cage implantation. To track the foraminal height deformations in response to each step of loading, four of the reflective markers used in tracking intervertebral motion were mounted on the superior and inferior bony edges of bilateral foraminal spaces. An algorithm was developed based on rigid body kinematic theory to calculate the amount of height changes. Nonparametric paired comparisons were conducted to compare the differences between the two cage groups.

RESULTS SECTION:
Foraminal Dimensions in Neutral Position: Results of instant molding in the unloaded neutral position showed that the median area of the narrowest cross-section of the foramens increased from 190.8 mm² (intact) to 224.5 mm² (with cages), or 17.0% increase (p<0.0005) for the tapered cage, and from 168.0 to 194.2 mm², or 16.5% increase (p<0.0005) for the cylindrical cage. The median value for the maximum foraminal height increased from 22.0 to 24.7 mm (or 9.8% increase, p<0.0004) for the tapered cage and from 21.3 to 23.1 mm (or 8.8% increase, p<0.0004) for the cylindrical cage. There was no statistically significant difference in either foraminal dimension between the two cage types.

Foraminal Height Change under Dynamic Loading: Loading in flexion produced bilateral height decrease of the foramens. Lateral bending caused height increase of the foramens on the convex side and height decrease on the concave side. The maximum deformations of the foraminal height in response to loading in each direction for the intact spines and after cages implantation are presented in Figs.1a and 1b. Significant reduction in foraminal deformation was observed after ALIF with cages in all loading directions and with both cage types. The amounts of reduction in foraminal height deformation with cages were normalized with respect to foraminal height deformation of the intact spine (Table 1). The cylindrical cages provided significantly more stabilization of the foraminal height than the tapered cages in flexion (74.0% vs. 18.2%, p<0.03), and marginally more stabilization in the concave side of the lateral bending (69.4% vs. 62.9%, p<0.059).

DISCUSSION:
Implantation of anterior interbody fusion cages, either cylindrical or tapered cages, produced increases in foraminal dimensions. In dynamic loading conditions, these cages also significantly stabilized foraminal heights. The amount of stabilization was influenced significantly by the loading direction, to a lesser degree by the cage type, and was strongly dependent on the fusion segment mobility. The study shows that stand-alone anterior interbody fusion cages are effective in restoring the foraminal height and stabilize the spine to withstand deformation of the foramens during daily loading.

REFERENCES