INTRODUCTION:
Significant C1-C2 instability is a serious condition that can lead to pain, myelopathy, or death if not treated. In certain cases unilateral fixation may be the only option due to comminuted fractures, anomalous vertebral artery trajectory, degenerative arthritis, or hemangioblastoma preventing bilateral screw placement. Therefore, the objective of this investigation was to compare the biomechanical characteristics of unilateral vs. bilateral C1-C2 fixation, specifically a C1 lateral mass (LM) screw and C2 intralaminar (IL) screw with an interconnecting rod. We hypothesized that the unilateral and bilateral C1-C2 fixation will result in progressively increased stability to the atlantoaxial joint by decreasing range of motion (ROM) and increasing stiffness compared to intact.

METHODS:
5 fresh-frozen human cadaveric cervical spines (C1-C3) were potted in a custom jig (Fig 1). The specimens were tested in flexion-extension, lateral bending, and axial rotation using a custom cervical spine testing system and an Instron material testing system (Fig 2A). Specimens were loaded from 0.5 Nm to 1.5 Nm of torque for 10 cycles. Data from the final cycle was used to determine ROM and stiffness (Nm/°) for each condition. The specimens were tested intact and, after a type II odontoid fracture, with unilateral and bilateral fixation constructs of C1 LM-C2 IL screws with an interconnecting rod (Fig 2B). The destabilized condition was not tested as could not resist loading torques. A paired t-test with a Bonferroni correction for multiple comparisons was used with a significance level of p < 0.05.

RESULTS:
The unilateral fixation decreased ROM in flexion-extension from 26.5° to 9.3° (p<0.001) and axial rotation from 52.6° to 12.2° (p=0.03) compared to intact (Fig 4). Lateral bending with unilateral fixation was found to be statistically equivalent to ROM in the intact state. The bilateral construct decreased ROM in axial rotation from 12.2° to 3.8° (p<0.01) and lateral bending from 12.3° to 6.3° (p=0.01) but there was no significant change in flexion-extension compared to the unilateral construct. The bilateral construct decreased ROM in flexion-extension from 26.5° to 6.0° (p<0.001), axial rotation from 52.6° to 3.8° (p=0.02), and lateral bending from 10.6° to 6.3° (p<0.01) compared to intact.

The only statistical difference in stiffness (Fig 5) was with ipsilateral rotation. The unilateral fixation decreased stiffness compared to intact from 0.86 Nm/° to 0.46 Nm/° (p<0.01). Ipsilateral rotation stiffness of the bilateral construct (1.67 Nm/°), however, was significantly greater than both the intact and the unilateral states (p<0.01).

CONCLUSIONS:
Atlantoaxial instability is a challenging clinical problem which may require instrumented stabilization of the motion segment. Bilateral instrumentation, although ideal, may not be feasible due to anatomic restrictions or other pathologies. The unilateral construct decreased ROM in flexion-extension and axial rotation compared to intact and resulted in stiffness values similar to the intact condition in all testing modalities, except for ipsilateral rotation. Although bilateral fixation offers greater stability, unilateral C1-C2 fixation using a C1 LM and C2 IL screw-rod construct may be useful in clinical situations where bilateral fixation is not possible.

SIGNIFICANCE:
This biomechanical study showed that a unilateral C1 LM and C2 IL fixation resulted in significant decreases in ROM in flexion/extension and axial rotation compared to intact while maintaining intact stiffness values. Although the bilateral construct offered further improvements, a unilateral construct may be useful in clinical situations where bilateral fixation is not possible.