Introduction
The causes of atlantoaxial instability include trauma, tumor, congenital malformation or rheumatoid arthritis. Commonly available fixation techniques to stabilize the atlantoaxial complex are several posterior wiring procedures (Brooks fusion, Gallie fusion), transarticular screw procedure (Magerl technique), either alone or in combination. Wiring procedures are obviously easier to accomplish however, these do not provide sufficient immobilization of the atlantoaxial complex. On the other hand, although transtalarcticular screw fixation (TSF) is much stiffer atlantoaxial arthrodesis than posterior wiring procedures, TSF has some drawbacks such as the injury of vertebral artery. Furthermore, body habitus (obesity or thoracic kyphosis) may prevent from achieving the low angle needed for correct placement of screws between C1 and C2. Recently, a new technique of screw and rod fixation (SRF) that minimizes the risk of injury to the vertebral artery and allows intraoperative reduction has been reported. The purpose of this study was to compare the biomechanical stability imparted to the C1 and C2 vertebrae by either TSF or SRF techniques in a cadaver model.

Methods
Ten fresh ligamentous human cervical spine specimens were harvested from cadavers. Occiput (C0) and C3 vertebra were potted to allow motion of the three segments between C0 and C3. In each specimen a system of rods was affixed to C0 for application of pure moment loads and C3 was potted and attached to a base in a testing frame. Infrared light-emitting diodes (LEDs) were attached rigidly to C0, C1, C2 and C3 vertebrae. The specimens were loaded to 2.0 Nm in five equal steps and the resulting spatial orientations of C0, C1, and C2 vertebral bodies with regard to C3 were recorded using an optical motion analysis system (Optotrak, Northern Digital, Inc., Waterloo, Ontario, Canada). The specimens were sequentially tested in the intact state, following injury and stabilization (unilateral-left side and bilateral), and after fatiguing to 5000 cycles (0.5Hz) at ±1.0Nm of flexion and extension, using a Materials Testing System (MTS Systems Corp. Minneapolis, MS). The injury consisted of transecting the transverse, ala, apical and capsular ligaments around the odontoid. The specimens were stabilized using TSF (screw diameter 3.5mm) in 5 spines or SRF (Cervifix, SYNTHES) in the other 5 spines. Further, in SRF group, the transverse connector was installed to link between both sides of rods together. The data was converted to angular displacements and the stabilized cases were compared to intact states for evaluating the efficacies of the two techniques in stabilizing the C1-2 segments. The differences in motion parameters within each fixation technique were compared using a two-tailed paired t-test. Statistical analysis between techniques was undertaken using a two-way unpaired t-test. In all cases, P<0.05 was considered statistically significant.

Results
In the TSF group (Fig.1), the unilateral fixation using one screw imparted a significant stability in only the axial rotation mode. Unilateral procedure in the SRF group (Fig.2) was effective in stabilizing in all modes except in extension. Difference in left and right lateral bending modes is due to unilateral application of the fixation device. The bilateral procedure in both of the groups was effective across the C1-C2 segment. However, the SRF group afforded higher stability than the corresponding TSF group in flexion and extension modes. The degree of stability did not change following fatigue, as compared to the pre-fatigue data. In the SRF group, the stability of the atlantoaxial complex increased in all motion directions except in right bending after installation of the additional transverse connector.

Discussion
Biomechanical evaluations of SRF have not been established. In the current study, we performed biomechanical testing to determine the stabilizing capabilities of SRF in comparison with conventional TSF. Stability in flexion and extension of SRF is superior to that of TSF. In unilateral TSF, the left lateral atlantoaxial joint acted as a fulcrum in left lateral bending. We conclude that in general a surgeon should undertake a bilateral fixation to achieve sufficient stability across the atlantoaxial complex and either technique will provide satisfactory results, although the SRF technique may be better in flexion and extension modes. One should use SRF procedure while trying to achieve stability with a unilateral system.

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