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INTRODUCTION:
The complex anatomy and biomechanics of the atlanto-axial motion segment impose technical challenges in the achievement of safe and successful surgical stabilization and fusion. The coauthors have recently reported successful clinical results using a novel C1-C2 stabilization technique employing C1 multi-axial posterior arch screws (MA-PAS) in a series of 3 patients (see Fig.1a-c) where anatomical anomalies precluded the use of conventional posterior fixation techniques [1]. The technically less demanding nature of MA-PAS technique, and its possible wider application in patients with normal anatomy, led the authors to compare the biomechanical stability of MA-PAS with two established multi-point fixation techniques (Magerl-Gallie and Harms) using non-destructive and destructive testing.

METHODS:
15 human fresh-frozen cadaveric occipital-C5 cervical spines (average age 77.4 [51-95]; 9 males and 6 females) were sourced from ScienceCare (USA) and randomly allocated to 3 equal groups. Muscle tissue was largely removed while ligaments were retained. Screws were passed up through adjacent end vertebrae such that the unrestrained motion was limited to between C0 and C4. The anterior and posterior ends of the spine were cemented into plastic cylinders using PMMA cement. Each spinal unit was then placed in a pure bending moment jig, and gripped via the plastic cylinders. The testing jig was controlled by a combination of an external stepper motor and an INSTRON testing system (see Fig. 2a-b).

RESULTS:
Non-destructive testing: The C1-C2 joint of the INTACT spines all demonstrated high flexibility in flexion-extension (ave 16.5deg) and axial rotation (ave 52.6 deg) while lateral bending (ave 2.7deg) was less compliant (see Fig.3). After instrumentation all specimens showed significantly reduced ROM in flexion-extension (MAGERL-GALLIE=4.2deg, HARMS=4.4deg, MA-PAS=4.2deg) and axial rotation (MAGERL-GALLIE=4.0deg, HARMS=0.59deg, MA-PAS=3.7deg) while lateral bend ROM of all instrumented specimens was similar or slightly greater than INTACT (HARMS=2.3deg, MAGERL-GALLIE=3.8deg, MA-PAS=5.3deg).

Destructive testing. MAGERL-GALLIE was the strongest requiring an average of 13.5Nm to cause failure (1 failure were due to wire breakage, 2 failures were due to disruption at an adjacent level). HARMS was weakest requiring 7.8Nm of torque (all failures were caused by pull out of the C1 screws). MA-PAS technique averaged 12.2Nm of torque to cause failure (4 failure were due to C1 arch fracture; 1 was at the adjacent level).

CONCLUSIONS:
The MA-PAS technique was shown to have similar rigidity and ultimate strength to the MAGERL-GALLIE and HARMS techniques in flexion-extension, axial rotation and lateral bend. The failure load in flexion was greater than the HARMS technique, and nearly as high as the MAGERL-GALLIE. Given the demonstrated biomechanical stability of the MA-PAS technique, it is proposed that this technique is an alternative to the technically demanding, and possibly more hazardous, conventional multi-point fixation techniques in patients with normal, as well as anomalous, C1/2 segmental anatomy.