Introduction

Aggressive tumor or inflammatory destruction of the second cervical vertebra (axis) can result in a complete loss of upper cervical structural integrity. Anterior reconstruction of the upper cervical spine is technically difficult due to its complex anatomy and biomechanics. Most contemporary constructs utilize a strut graft or single mesh cage with plate or screw fixation. Recently, a novel device consisting of a titanium mesh cage with bilateral wings combined with a T-shaped plate has provided excellent clinical results in a series of 14 patients. Posterior C3 fixation, either cranio-cervical (C0-C3) or cervical-only (C1-C3) is mandatory in order to achieve adequate stability. Biomechanical comparisons of this novel device with traditional treatment options have not been reported. Accordingly, we evaluated 4 different constructs used for C2 reconstructions in order to delineate any differences in acute stability provided by these hardware configurations.

Methods

Five fresh-frozen human cadaveric cervical spines with the occiput (C0-C5) were used in this study. All peri-spinous soft tissue was removed, with care taken to preserve the joint capsules, ligaments and osseous structures. The C5 vertebra was constrained to the testing apparatus and loads were applied to the occiput. The specimen was tested in its intact condition. Following placement of the C1-C3 posterior instrumentation system (polyaxial screw/rod construct), a complete resection of the second vertebra was performed. Two anterior fixation constructs were examined: (1) a novel Ti mesh cage with screw fixation to C1 and C3 and (2) an anterior plate augmented with a circular wood dowel (simulating an anterior strut graft, Fig. 1). Each anterior construct was tested with C0-C3 and C1-C3 posterior fixation, yielding 4 separate fixation groups. Occipital fixation was achieved by extending the posterior instrumentation superiorly, using an occipital plate with individually bent bilateral rods attached to the occipital plate and to the C1 and C3 screws using locking nuts. Cervical-only posterior fixation (C1-C3) was achieved by inserting shorter posterior rods without removing the screws placed into C1 and C3.

Pure moment loads (up to 1.5 N-m) were applied in flexion and extension, right and left lateral bending, and right and left axial rotation using a weight and pulley system attached to a fixed, rigid metal frame. Relative intervertebral motion was determined for the C1-C3 segment using a 3 camera motion analysis system that tracked marker triads on each vertebral level. Statistical significance was evaluated using a one-way repeated measures ANOVA with Student-Newman-Keuls (SNK) post hoc pairwise comparisons to delineate differences in intervertebral motion between fixation constructs.

Results

The results indicate that all fixation scenarios provided a statistically significant decrease in motion in a severely destabilized cadaveric C2 corpectomy model as compared to the intact condition (Fig. 2). The data also showed that there was no significant difference in C1-C3 intervertebral motion between the 4 constructs, regardless of whether the occiput was included in the fixation. However, in flexion/extension and lateral bending, the plate/graft construct reduced motion more than the cage construct when only C1-C3 posterior instrumentation was used. These differences were eliminated when the posterior instrumentation was extended to include the occiput. The cage construct better restricted C1-C3 axial rotation when only posterior instrumentation was used, however, these systems afforded equivalent motion when occipital fixation was added.

Discussion

Anterior reconstruction of the second cervical vertebra following corpectomy or spondylectomy (removal of the entire vertebral body) has to be performed with constructs that provide immediate stability resisting flexion-extension and axial rotation forces. Both constructs tested in our study meet this aim. The most interesting finding in our study is that the occiput does not need to be included in the posterior instrumentation. By leaving the C0-C1 joint intact, the patient’s sagittal plane range of motion in the cranio-cervical junction can be preserved to some extent. Our data indicate that a construct consisting of a T-shaped plate combined with anterior support and posterior instrumentation provides equivalent acute stability in a totally disconnected cervical spine after complete removal of C2. However, from a clinical standpoint, using a titanium mesh cage rather than a strut graft may prevent donor site morbidity, risk of dislodgment, or fatigue failure of the strut graft.

The results in this study also reflect the clinical findings with different replacement techniques for the second vertebral body: plate and strut graft constructs provide good primary stability for flexion-extension. Nevertheless we have observed clinical failures with the plate constructs resulting from dislodgement or graft fatigue. With the new replacement device we have experienced no hardware failures to date. The small cages fixed bilaterally to the central cage provide an excellent support for the lateral masses of C1, increasing resistance against rotational forces. This study represents the worst case scenario, entire removal of the second vertebral body. Clinically, this might not always be necessary. In most patients an anterior resection of the body of C2 together with the odontoid (after removal of the anterior ring of C1) is sufficient. In these patients we tend to perform posterior fixation from C1 to C3. After resection of anterior and posterior elements, the posterior cranio-cervical fixation (C0-C3) provides the safer stabilization. This seems to be in accordance with the finding of this study, especially with respect to axial rotation.

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