**INTRODUCTION**

Spinal fixation using rigid short segment instrumentation is often used in the thoracolumbar spine. Problems such as implant loosening and adjacent segment changes are frequent in the osteoporotic spine. To enhance fixation, one strategy is to extend the posterior fixation to adjacent levels. However, this may exacerbate the adjacent segment changes. Another strategy to enhance fixation is cement augmentation.

The goals of this study were to determine the effect of posterior instrumentation extension and/or cement augmentation i) on immediate stabilization of the instrumented level and ii) on biomechanical changes adjacent to the spinal instrumentation. A combined testing protocol that used both a traditional flexibility method and a hybrid technique [1] was adopted in a long segment thoracolumbar cadaveric model.

**METHODS**

The study was designed for repeated measures comparison to test the effects of posterior rod extension and cement augmentation. The basic construct was a T9-L3 human cadaveric segment (Fig.1A) with a T11 vertebrectomy, replacement with an extendable vertebral body replacement device (Synex, Synthes Spine, Mississauga, ON), pedicle screws (US$ 0 5 mm, Synthes Spine) and rigid rod fixation bridging across T10-T12 (Fig. 1B). The constructs to evaluate the effect of rod extension to L1 are shown in Fig 1C (rigid) and Fig 1D (flexible).

Twelve 7-vertebra thoracolumbar cadaveric specimens (T9-L3 or T8-L2) were utilized in this study. Flexibility tests with +/-5 Nm pure moments in flexion-extension (FE), axial rotation (AR) and lateral bending (LB) were carried out at 2 degrees/second for 3 cycles in each direction. Flexibility tests were first carried out on the intact specimen (Fig 1A), followed by surgical conditions without cement (Figs 1B, C, D) and lastly after cement augmentation of screws. Our Institutional Clinical Research Ethics Board approved this study.

The T12 and L1 pedicle tracts were over drilled with Ø 5 mm drill bit to simulate loosen screws in the osteoporotic spine [2]. The T10 screws were not over-drilled but instead were cemented so as to keep the superior segments constant. The flexible acetal extension rods used in this study are not clinically approved but were chosen as a matched comparison to the rigid rods to test the concept of flexible extension. The ratio of the stiffness of the flexible acetal rods (Ø 6.35 mm) to the stiffness of the rigid stainless steel rods (Ø 6 mm) were 1:37, from 3-point bending tests.

Motions in 3-D of all vertebral bodies (except T11) were collected using an optoelectronic camera system (Optotrak 3020, Northern Digital Inc., Waterloo, Canada). Strain gauges (TML FLG-02-23, Tokyo Sokki Kenkyujo, Tokyo, Japan) attached to the spinous process and left and right lateral aspects of the L1 and L2 vertebral body monitored vertebral body strains during flexion-extension and lateral bending tests. Intersegmental ROMs were determined from flexibility curves at the third (fast) cycle and normalized against its intact condition for each surgical configuration so as to reduce effects of inter-specimen differences. Normalized motion across the destabilized levels was compared using the flexibility protocol. Normalized motion and strain at the caudal adjacent levels were compared using a hybrid protocol. In the hybrid testing protocol, post-test comparisons were carried out across conditions at the same overall range of motion (ROM). The maximum ROM of the stiffest surgical construct was used as the baseline for comparison.

Two-way repeated measures ANOVA analyses were carried out between cement augmentation (factor 1) and the posterior rod extension (factor 2) on each flexibility test direction for ROM and strains. An alpha of 0.05 was chosen. Newman-Keuls post-hoc analyses were carried out to compare between surgical techniques.

**RESULTS**

*Destabilized level, using flexibility protocol.* Mean ROM across destabilized level (T10-T12) in the intact spine were 9.3°, 7.8°, 6.2° in AR, LB, and FE respectively. Without cement augmentation and with rigid, flexible or no extension, ROMs were reduced by 27-64% in FE, 13-39% in AR and 29-67% in LB. With cement augmentation, higher reductions of ROMs were found (by 62-76% in FE, 51-61% in AR, 73-82% in LB). The main effect of cement augmentation on mean normalized ROM was significant in AR (p = 0.002), LB (p = 0.003) and FE (p = 0.003). Posterior extension rods also significantly reduced mean normalized ROM in AR (p < 0.0001), LB (p < 0.0001) and FE (p < 0.0001).

*Caudal adjacent levels, using hybrid protocol.* With cement augmentation only, ROM of the first level below the destabilized region (i.e. T12-L1) was significantly increased in FE (mean = 15%), AR (49%, Fig 2) and LB (22%). Inclusion of posterior extension reduced ROM to values closer to intact in AR (+10% with flexible and –17% with rigid, Fig 2), and lower than intact in LB (by 42-58%) and FE (by 51-73%). ROM of the second level below (i.e. L1-L2) was significantly increased with cement and/or extension in all directions. Strains on adjacent vertebrae were significantly increased at all measurement sites following cement augmentation and/or posterior extension. Flexible extension rods resulted in significantly different ROM and strains than with rigid extension rods or no extension rods.

**DISCUSSION**

The goals of this study were to determine the effect of posterior instrumentation extension and/or cement augmentation i) on immediate stabilization of the instrumented level and ii) on biomechanical changes adjacent to the spinal instrumentation. ROMs in all directions at the destabilized and extension levels were significantly affected by both extension and/or cement.

This study is the first to present data using the hybrid flexibility-stiffness protocol, to our knowledge. Length of specimen is an important factor in studies on adjacent level effect. The 3 mobile segments below the instrumented level in the current study isolated end effects due to proximity to the potting cement and allowed effects at 2 adjacent levels to be studied.

The results of this study suggested that cement augmentation only would result in enhanced stabilization but possible adjacent level effects due to increased motion and strain, while flexible extension rods would reduce biomechanical changes at the level of extension.


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