Optimal Cement Dose & Configuration for Prophylactic Vertebroplasty Above Long Thoracolumbar Fusion Constructs to Reduce Proximal Junction Kyphosis (PJK): A Finite Element Model

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Introduction

- PJK is not uncommon after spinal deformity surgery and has prevalence rates reported as high as 61.7%.

- PJK can result in significant post-pain and complication.

- Revision rates are highest secondary to fracture at the UIV and UIV+1.

- Etiology of PJK - multi-factorial
  - Surgical
  - Radiographic (SVA, PI-LL mismatch)
  - Patient-related
    - Poor bone quality
Fractures occurred in 12 of 18 specimens
- 5 in the control group
- 6 in the one-level group
- 1 in the two-level group

Revision rate for 2-level cement 0% vs. 19% for non-2-level cement (P=0.02).
Our Previous Work

- Evaluated a tapered dose of cement in T10 (4cc), T9 (3cc), and T8 (2cc)
- Reduced junctional endplate stresses in an FE model.
- Eliminated the incidence of VCF in a cadaveric model.
Hypothesis

- Does location and dosage of cement matter?
- Varying the location and dosage of vertebral cement will further affect endplate stresses.
  - Influence rates of VCF and possibly PJK.

Figure 1: Cement positions: (A) Anterior, (B) Center, (C) Lateral Left, (D) Lateral Right.
Methods

- A validated Finite Element (FE) model from T6 - pelvis was used for analyses.

- An osteoporotic model was developed and modified by the insertion of screws and rods from T10-S1, simulating the standard surgical procedure in-silico.

- Varying doses of PMMA bone cement were injected into different locations within the T10, T9, and T8 vertebra.
Different cement configurations were simulated (central, anterior, lateral right, lateral left, and staggered).

A compressive load was applied 10mm anterior to the center of the T6 vertebrae to simulate a flexion moment.

Endplate stress and posterior ligamentous strain from T7 to T10 were analyzed.
Results

- **Anterior cement placement (4cc, 3cc, 2cc)**
  - 26% decrease in endplate stress at T9.
  - 21% decrease at T8.
  - 2% decrease in posterior ligamentous strain at T8-T9.
- **No increased endplate stresses at unadulterated T7.**
Optimal Cement Dosage

Change in Stress at T8 Sup & T7 Inf endplates for the tapered cement dosage

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
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<td>4</td>
<td>4</td>
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<td>2</td>
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<td>3</td>
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<tr>
<td>T8 (cc)</td>
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<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
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</table>
Stress Values for Different Cement Location

Stress for different placement of T10- 2.5cc, T9- 2cc, & T8- 1cc

- A: Anterior, C: Center, AC: Anterior-Central placement

Lowest Endplate Stresses: Anterior - T10, Anterior Central - T9, Central - T8
Conclusions

- Lowest observed endplate stresses in this osteoporotic FE model
  - Cemented T10, T9, & T8
  - **Non-cemented unadulterated T7**
    - Optimal dose
      - T10 (UIV) - 2.5cc anteriorly
      - T9 (UIV+1) - 2cc anterior central
      - T8 (UIV+2) - 1cc central
Conclusion

- Poor bone quality is a concern in most ASD patients due to their age.
- Construct stiffness and poor bone quality are risk factors for PJK.

**Optimal dosage & placement**
- T10 (UIV) - 2.5cc anteriorly
- T9 (UIV+1) - 2cc anterior central
- T8 (UIV+2) - 1cc central

- A decrease in maximal endplate stress is beneficial.
- Translates to increase force required for endplate failure.
- Reduce VCF and possibly PJK.