

Junctional Pathology – Significance & Techniques for Avoidance

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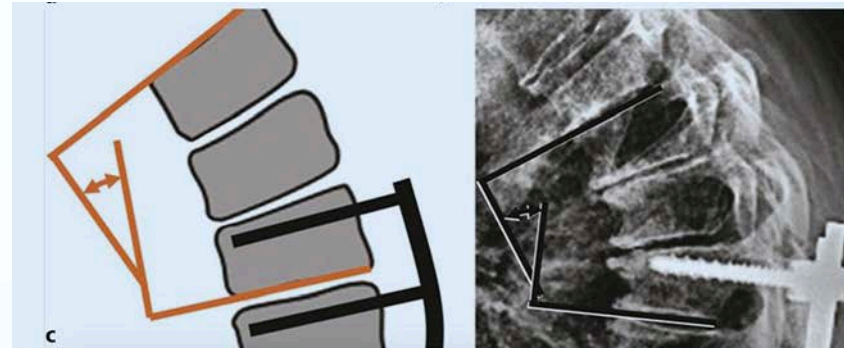
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Disclosures

- Consultant - Zimmer / Biomet, DePuy Synthes Spine, Amendia, Stryker
- Stock - Innovative Surgical Solutions, Vivex
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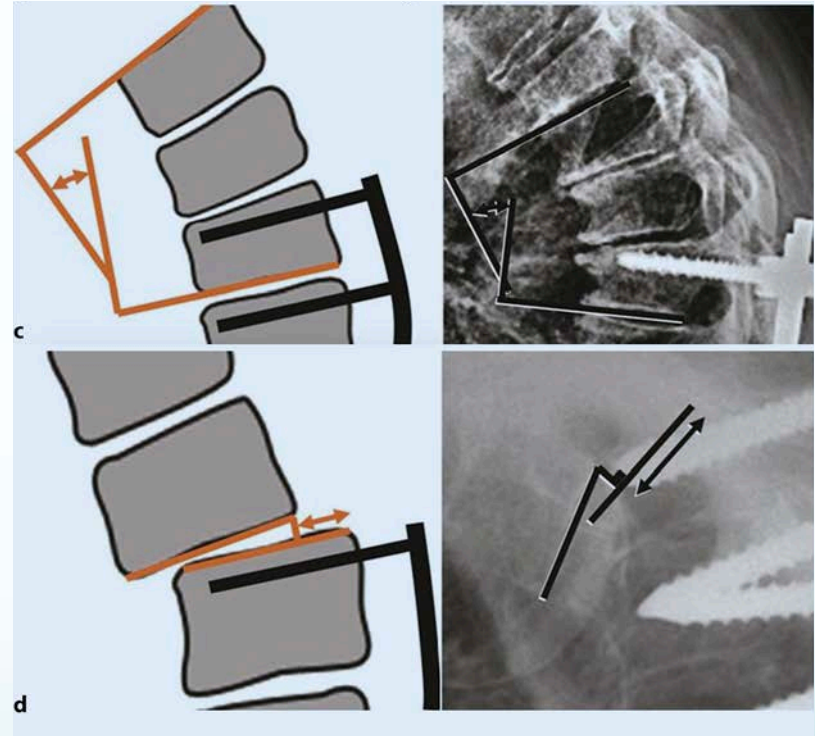
PJK

- Traditionally, PJK has been defined as a change of at least 10° in the proximal junctional sagittal Cobb angle from the preoperative value.
- Most authors have radiographically identified PJK when observing a kyphosis of $\geq 10^\circ$ develop between the inferior endplate of the upper instrumented vertebra (UIV) and the superior endplate of the two supra-adjacent vertebrae.



Refined PJK Thresholds

- Lafage et al. redefined the thresholds of proximal junctional pathologies call for **expansion** of radioradiographic PJK criteria.
- Accounting for **sagittal listhesis** (from UIV to first supra-adjacent vertebra)
- And **grouping by UIV** (T8 and above; T9 and below).
- The new criteria were able to identify 20% of patients who underwent revision for proximal junctional pathologies (vs. 7% identified by classic criteria),
- Enhancing the utility of radiographic PJK criteria for predicting future revision surgery.



Acute Proximal Junctional Failure

- Acute proximal junctional failure (APJF) was recently defined by the International Spine Study Group (ISSG) as:
 - Post-operative fracture of the upper instrumented vertebrae (UIV) or UIV + 1.
 - UIV implant failure.
 - Proximal junctional kyphosis (PJK) increase > 15 degrees.
 - Need for proximal extension of the fusion within 6 months of surgery.



Proximal junctional kyphosis following adult spinal deformity surgery

Samuel K. Cho · John I. Shin · Yongjung J. Kim

- A systematic review was performed to assess the prevalence, risk factors, and treatments of PJK.
- Analyzed 33 studies that reported the prevalence rate, risk factors, and discussions on PJK following spinal deformity surgery.
- **Prevalence rates varied widely from 6 to 61.7 %.**
- **Clinical outcomes for patients with PJK were not significantly different from those without PJK.**
 - One recent study revealed that **adult patients with PJK experienced more pain.**
- **Risk factors for PJK included**
 - Increased age at operation
 - Low bone mineral density
 - Shorter fusion constructs, UIV below L2
 - Inadequate restoration of global sagittal balance.
- Prevalence of PJK was high but not as clinically significant.
- Careful and detailed preoperative planning and surgical execution may reduce PJK in adult spinal deformity patients.



Bimodal Incidence and Causes of Proximal Junctional Kyphosis (PJK) in Adult Spinal Deformity (ASD)

Munish C. Gupta MD, Bassel G. Diebo MD, Themistocles S. Protopsaltis MD, Robert A. Hart MD, Justin S. Smith MD, PhD, Christopher P. Ames MD, Renaud Lafage MSc, Justin K. Scheer BS, Han Jo Kim MD, Shay Bess MD, Douglas C. Burton MD, Peter G. Passias MD, Frank J. Schwab MD and Virginie Lafage PhD

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- Gupta et al. identified a bimodal incidence and temporal pattern of PJK.
- aPJK < 6 weeks,
- cPJK > 1 year.
- aPJK was found to have an increased incidence of 40.3% vs. cPJK at 22%.
 - Associated with higher revision rates (21% vs. 10.3%).
 - aPJK occurred in 50/70 (71.4%) of **posterior-only approaches** vs 21/40 (52.5%) in combined approaches, p<0.05.

Risk Factors

Non-Modifiable

- Age and magnitude of deformity
- Body mass index (BMI) and bone mineral density (BMD)
- Neuromuscular envelope
- Comorbidities and risk stratification

Modifiable

- Surgical approach
- Sagittal realignment
- Junctional zone

Age & Magnitude of Deformity

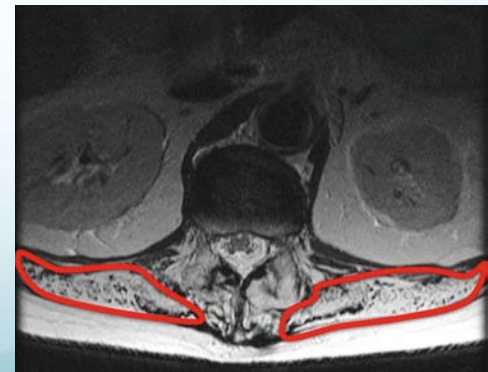
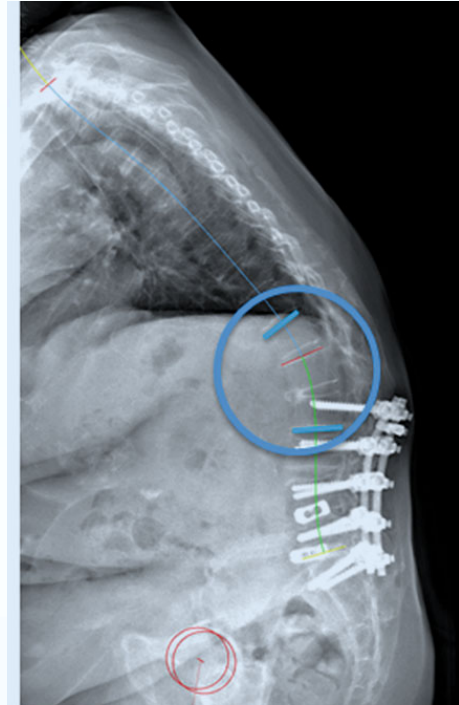
- **> 55 years old** are at increased risk of sustaining PJK.
 - Lafage et al. found that PJK in these patients is likely driven by sagittal plane overcorrection.
- Preoperative presence of substantial sagittal malalignment and magnitude of deformity are also considered risk factors for PJK and proximal junctional failure.
- High preoperative **sagittal vertical axis (SVA)** and **thoracic kyphosis** are parameters of particular note.
- This emphasizes the necessity for **patient-specific treatment, especially for older patients** whose age and magnitude of deformity may require different alignment goals than younger patients.

Body Mass Index (BMI) & Bone Mineral Density (BMD)

- ↑ **body mass index (BMI)** can result in increased biomechanical stress placed on the UIV.
 - No BMI cutoff value at which PJK risk increases has yet to be identified.
- ↓ **bone mineral density (BMD)** is a risk factor for PJK.
 - Weaker bone-to-screw interface, increasing the risk of screw pull-out post-instrumentation.
 - Increased risk of adjacent segment disease following spinal fusion.

Neuromuscular Envelope

- **Fatty infiltration** of the muscular envelope can contribute to the development of spino-pelvic muscular asymmetry and has been implicated in PJK development.
- Hyun et al. demonstrated that PJK might result from reduced pre-operative muscularity and increased fatty degeneration within the thoracolumbar musculature.
 - May promote sagittal spino-pelvic malalignment in the setting of ASD and contributes to the development of PJK.
- **Assess thoracolumbar muscularity and degree of fatty degeneration at the junctional area of the UIV of choice.**



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Study Group

Does Minimally Invasive Percutaneous Posterior Instrumentation Reduce Risk of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery? A Propensity-Matched Cohort Analysis

- 68 patients cMIS (perc screws) group, and 68 patients HYB (open screws) group compared from a multicenter database.
- Mean number of levels treated posteriorly was 4.7 for cMIS and 8.2 for HYB ($P < 0.001$).
- Oswestry Disability Index scores were significantly improved in both groups.
- Radiographic PJK was defined as proximal junctional angle > 10
 - **Radiographic PJK developed in 31.3% of the cMIS and 52.9% of the HYB group ($P = 0.01$).**
 - **Reoperation for PJK was 4.5% for the cMIS and 10.3% for the HYB group ($P = 0.20$).**
- **Sub-group analysis for patients undergoing similar levels of posterior instrumentation in the cMIS and HYB groups found a PJK rate of 48.1% and 53.8% ($P = 0.68$)**
 - **Reoperation rate of 11.1% and 19.2%, respectively ($P = 0.41$)**
- Overall rates of radiographic PJK and reoperation for PJK were not significantly decreased with MIS pedicle screw placement.
- However, a larger comparative study is needed to confirm that MIS pedicle screw placement does not affect PJK.

Comorbidities & Risk Stratification

- Presence of **comorbidities is a well documented risk factor for PJK** following ASD realignment surgery.
 - Diebo et al. developed a novel index to quantify collective morbidity risk of ASD realignment surgery, utilizing preoperative comorbidities among several parameters from the Nationwide Inpatient Sample (NIS).
 - Pulmonary circulation and neurological disorders, among others, were identified as contributors to ASD risk.
- Frailty has also been reported to predispose to PJK.
 - Miller et al. created a deformity-specific frailty index (ASD-FI)
 - Patients with **frailty and severe frailty (0.3–0.5; >0.5, respectively) had ↑ PJK**, offering surgeons another useful tool for treatment optimization.

Modifiable Risk Factors

Surgical Approach

- Several cadaver and biomechanical studies suggest that development of PJK is associated with posterior soft tissue and intervertebral elements disruption.
- The **combined anteroposterior approach** = risk factor for PJK.
 - Stiffer construct?
- However, Liu et al. & Gupta data contradict this claim.
- **Preserve the tension band.**

Sagittal Realignment & Larger Magnitude of Deformity Correction

- Multiple studies concluded that **overcorrection of lumbar lordosis (LL) and SVA both contribute to PJK onset.**
- Dubousset's cone of economy: sagittal alignment overcorrection disrupts the equilibrium between SVA and the natural line of gravity.
 - The body tries to self-correct to an optimal position but is restricted to the remaining unfused segments following extensive fusion.
- Lafage et al. all patients who developed PJK demonstrated global alignment overcorrection in all age groups.
 - **Connection between overcorrection and PJK magnitude.**
- Overcorrection was once favored for older patients to gradually counter alignment degeneration, yet it does not account for age and patient-specific alignment goals.
- More comprehensive preoperative plan: **PI = LL**

Junctional Zone

- UIV selection at the **thoracolumbar junction**, specifically between T11 and L1, is associated with PJK.
 - Lafage et al. confirmed a significantly **increased rate and risk of PJK in patients with UIV at a lower thoracic level.**
- The nature of the construct and instrumentation selected has also been examined. Utilization of hooks over pedicle screws has been associated with lower proximal junctional angle.
 - Metzger et al. concluded that placement of bilateral **supra-laminar hooks** at the UIV was **superior** to all other hook and / or pedicle screw combinations, producing reduced hypermobility at the supra-adjacent non-instrumented segment.
- Han et al. demonstrated CoCrMRC, in comparison to TiTRC rods improved rod stiffness, construct stability, and potential to reduce rod breakage.
 - The increased stiffness in **CoCrMRC increased the risk of PJK** occurrence and impacted the time-frame within which PJK develops.
 - **TiTRC** patients developed PJK between **2 and 84 months**
 - All PJK cases related to **CoCrMRC** occurred **within 7 months post-op.**

Basic Science

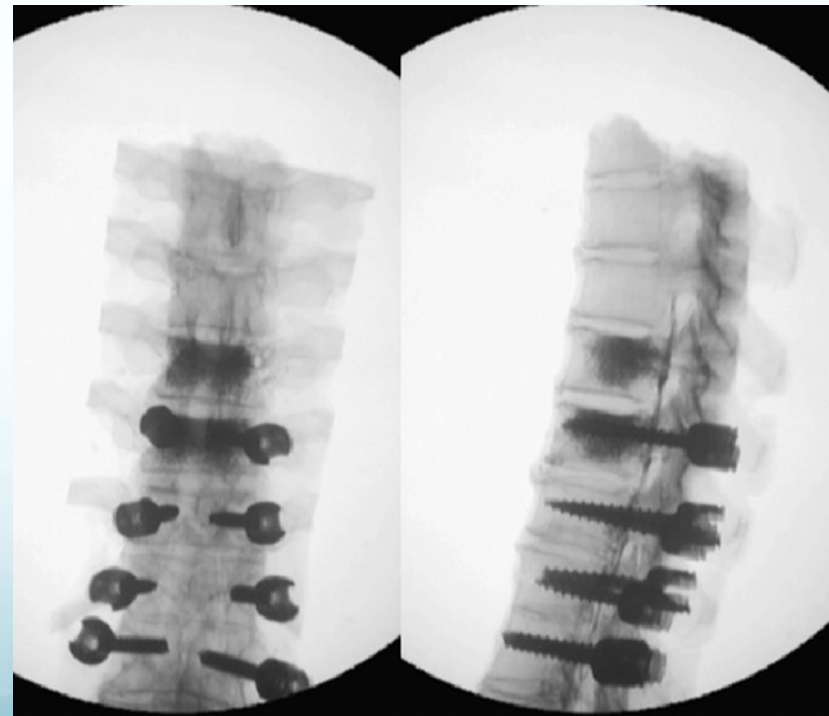
Use of vertebroplasty to prevent proximal junctional fractures in adult deformity surgery: a biomechanical cadaveric study

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Ivan E. LaMotta, MD, Gabor D. Voros, MD, Stephen M. Belkoff, PhD, MPH

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- Cadaveric study
- Cemented UIV & UIV + 1
- **Fractures occurred in 12 of 18 specimens**
 - **5 in the no cement group**
 - **6 in the one-level cement group**
 - **1 in the two-level cement group**
- These differences were statistically significant.

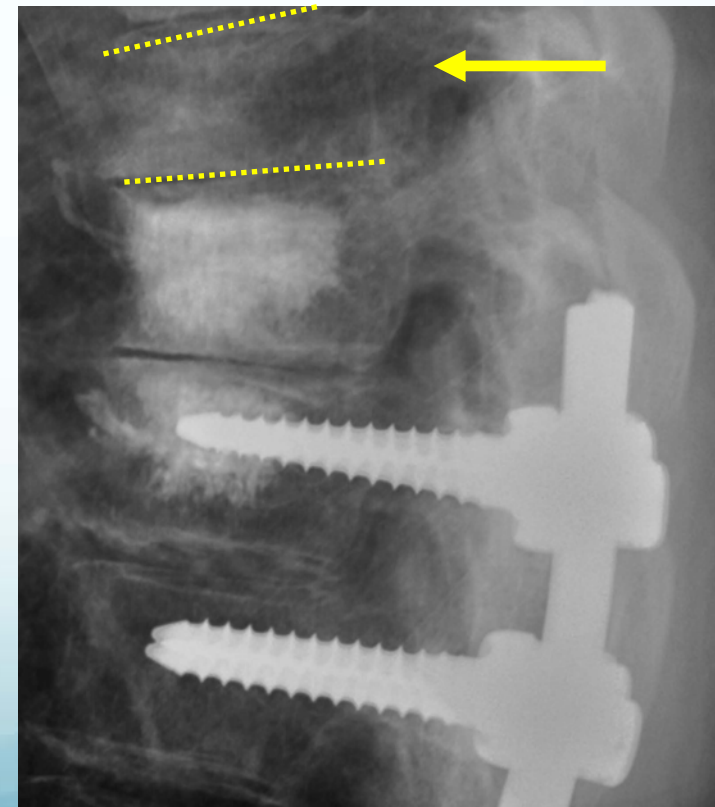


DEFORMITY

Prevention of Acute Proximal Junctional Fractures After Long Thoracolumbar Posterior Fusions for Adult Spinal Deformity Using 2-level Cement Augmentation at the Upper Instrumented Vertebra and the Vertebra 1 Level Proximal to the Upper Instrumented Vertebra

Alexander A. Theologis, MD,* and Shane Burch, MD*

- 51 patients met inclusion criteria
 - 19 patients - 2-level cement
 - 23 – No cement
 - 9 – Other (received cement-augmentation at a portion of the proximal extent of the fusion construct placed based on surgeon preference.
 - **Average follow-up: 15 - 25 months**
- **Revision rate for 2-level cement 0% vs. 19% for non-2-level cement (P=0.02).**
- After UIV adjustment, risks of PJF revision surgery were 13.1 times higher for “Other” (95% CI: 0.5–346.5, P = 0.12)
 - 9.2 times higher (95% CI: 0.4–239.1, P = 0.18) for no-cement.



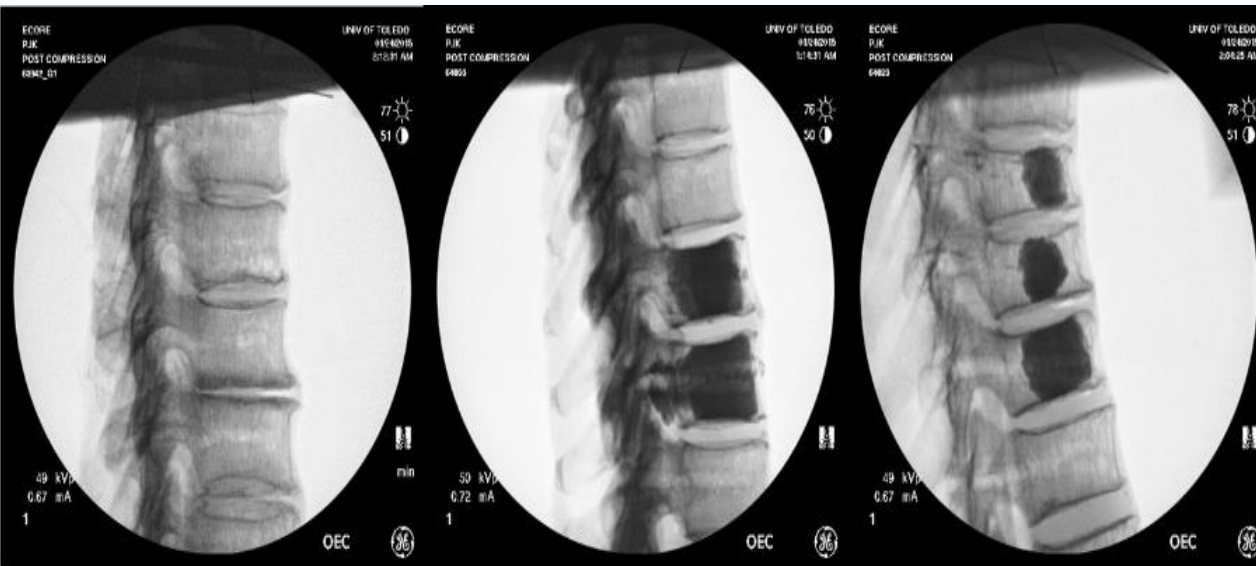
Clinical Study

The effect of prophylactic vertebroplasty on the incidence of proximal junctional kyphosis and proximal junctional failure following posterior spinal fusion in adult spinal deformity: a 5-year follow-up study

Tina Raman, MD*, Emily Miller, MD, Christopher T. Martin, MD, Khaled M. Kebaish, MD

- 39 patients, 28.2% developed PJK (11: 7.7% at 2 years, 20.5% between 2 and 5 years), and 5.1% developed acute PJF.
- 2 / 11 PJK patients required revision for progressive worsening of the PJK.
- There were **no proximal junctional fractures**.
- There was no significant difference in ODI, SRS-22, or SF-36 scores between those with and without PJK or PJF ($p > .05$).
- Prophylactic vertebroplasty **may minimize the risk for junctional failure** in the early post-operative period.
- **Does not appear to decrease the incidence of PJK at 5 years.**

Previous Work



Group 1-Instrumentation **Group 2-Instrumentation +4cc Group** **Group 3-Instrumentation +4cc+3cc+2cc**



- 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 .

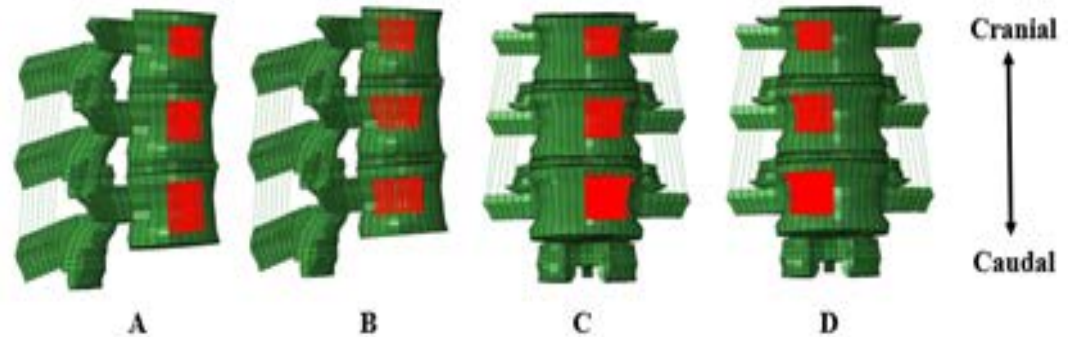
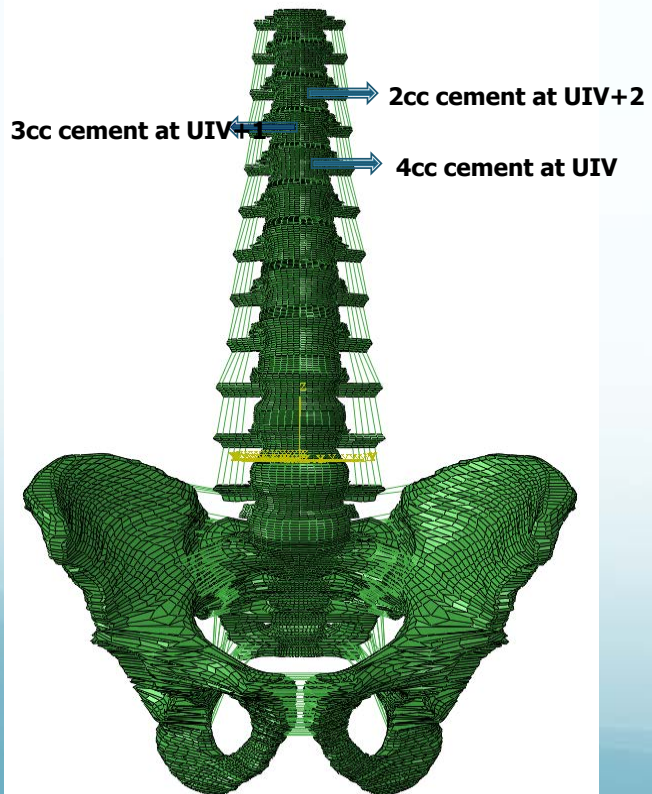
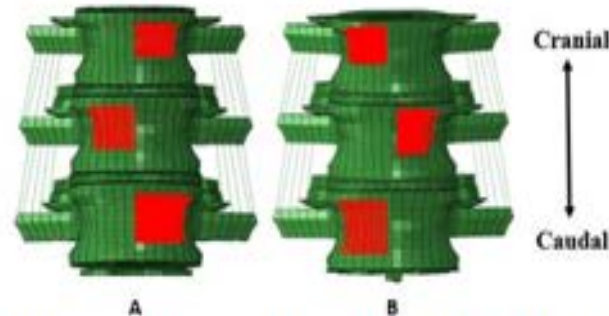
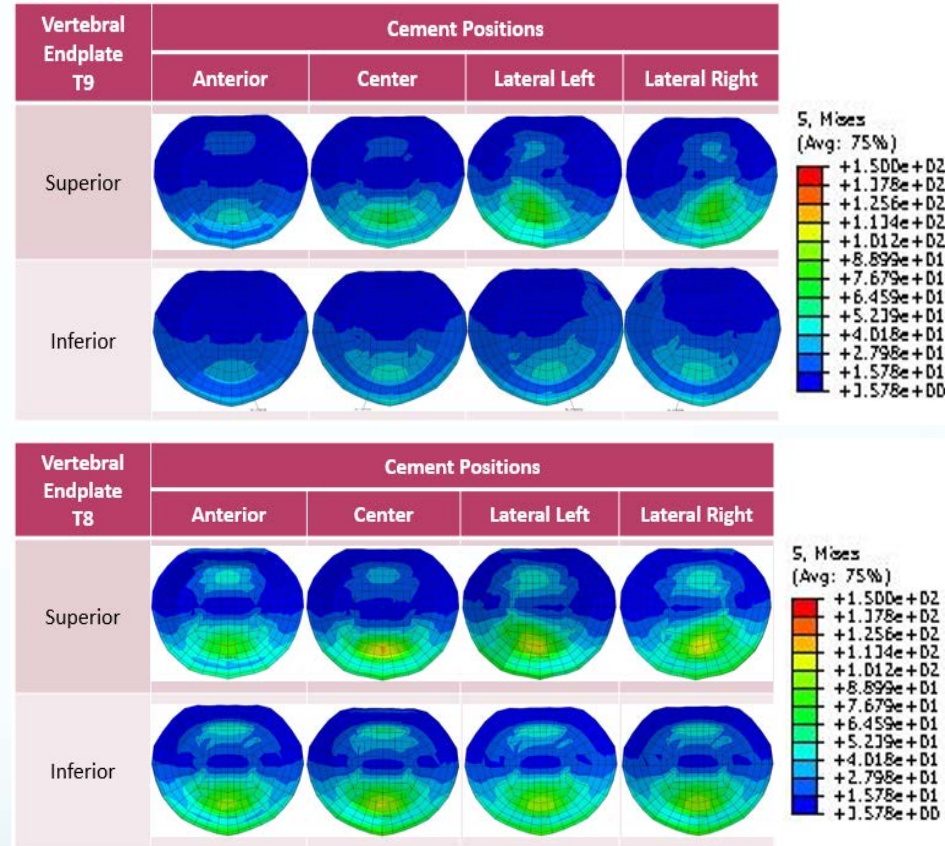


Figure 1: Cement positions-(A) Anterior, (B) Center, (C) Lateral Left, (D) Lateral Right



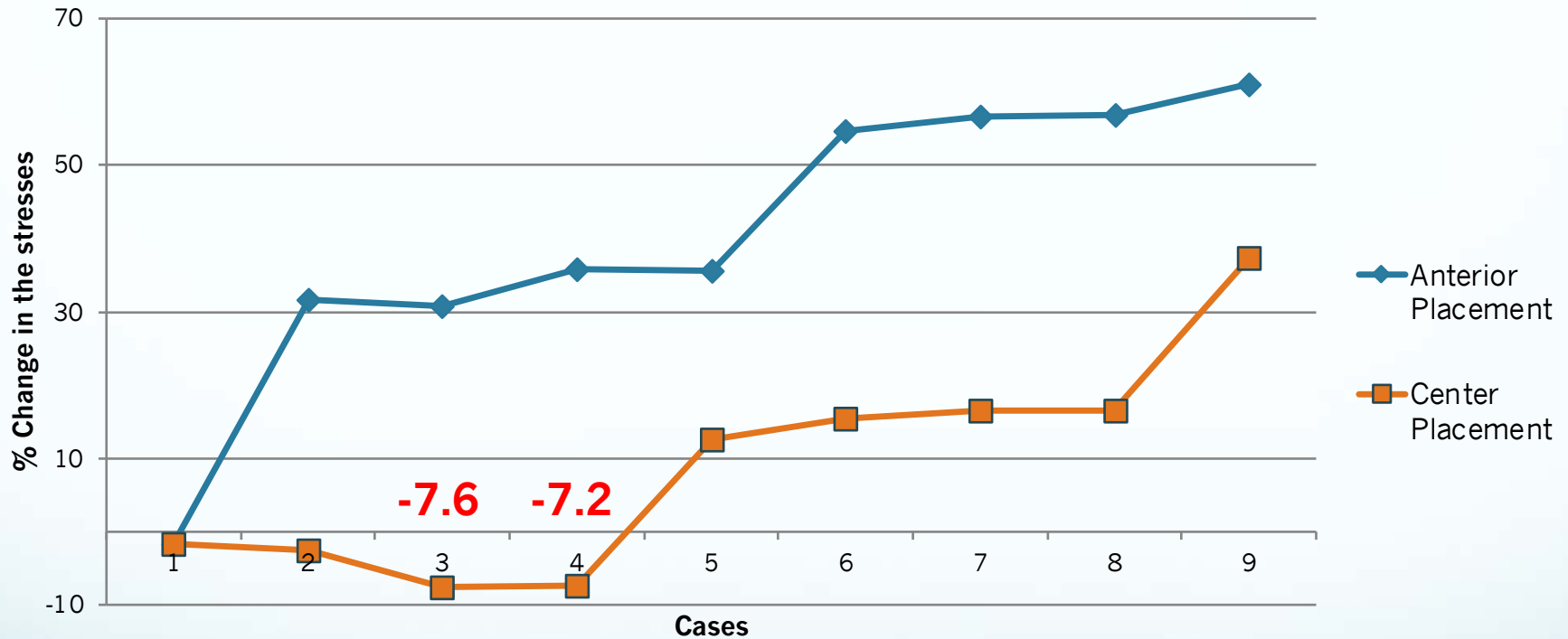
Results

- 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 T7.**



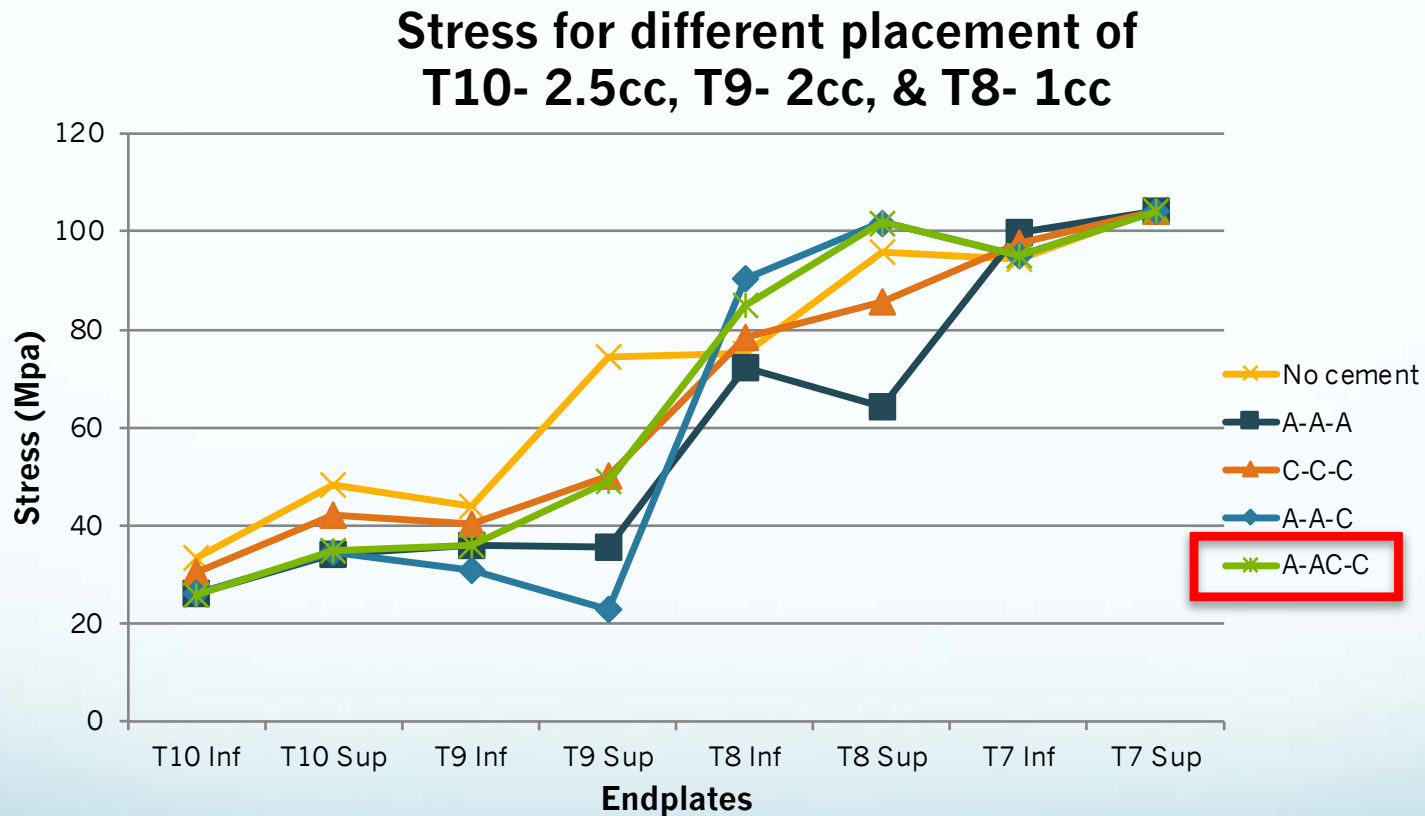
Optimal Cement Dosage

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



Case	1	2	3	4	5	6	7	8	9
T10 (cc)	0	2	2.5	3	4	4	3	4.5	5
T9 (cc)	0	1.5	2	2.5	3	3.5	3	4	4
T8 (cc)	0	0.5	1	1.5	2	2.5	3	3	3.5

Stress Values for Different Cement Location



- 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**

Predictive Factors for Acute Proximal Junctional Failure after Adult Deformity Surgery with Upper Instrumented Vertebrae in the Thoracolumbar Spine*

Prokopis Annis¹ Brandon D. Lawrence¹ William R. Spiker¹ Yue Zhang² Wei Chen²
Michael D. Daubs³ Darrel S. Brodke¹

- 135 consecutive patients with minimum 2-year follow-up, fusions were divided into 3 cohorts based on the UIV location (T9–T10 vs. T11–T12 vs. L1–L2).
- **The incidence of APJF was 38.5%, with a trend toward higher APJF in the T9–T10 group (p = 0.07)**
- **UIV was at T10, the incidence of APJF was 57.1%**, significantly higher than T9 and T11 (p=0.03 and p=0.01).
 - Overall revision rate for APJF was 17%,
- **Risk factors for APJF**
 - Pre-op sagittal vertical axis > 5 cm
 - Post-op PJA > 5 degrees
 - Thoracic kyphosis > 30 degrees
 - Instrumentation to the pelvis as risk factors for APJF.
 - Greater correction of lumbar lordosis (LL)
- **Fracture at the UIV lead to the highest revision rate.**
- **PJK > 15 degrees WITHOUT fracture or hardware failure had the longest revision-free survival (2-5 years, 100%).**
- **Post-op PJA > 5 degrees and greater correction of LL are independent risk factors for APJF.**

- Further clinical analysis is required.

- To date:

- 14 patients with UIV at the T/L junction
- Mean DEXA T-score -2.6
- Mean follow-up 32 months
- **Tapered cement UIV, UIV + 1, UIV + 2**
- **PI + LL +/- 10**
- **No PJK**



Conclusion

- Recommendations that may decrease the rate of PJK:
 - **Preserve the posterior intervertebral elements (soft tissue) at and above the UIV.**
 - **Preserve the proximal facets and posterior ligaments.**
 - **Use supra-laminar hooks or tapered rods vs. pedicle screws at the UIV.**
 - **Do not overcorrect, particularly in patients > 55 y.o. PI = LL**
 - **Prophylactic vertebral cement UIV, UIV + 1 / UIV + 2 / tapered dose?**

Thank You

