Calculation of Optimal Bone Cement Dosage and Location for Prophylactic Vertebroplasty during Long Thoracolumbar Fusion to Reduce the Occurrence of Proximal Junction Kyphosis (PJK) - A Finite Element Study

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ABSTRACT INTRODUCTION: Long segment fusion is often utilized in the treatment of symptomatic spinal deformity. The incidence of proximal junctional failures is one of the main cause of proximal junction kyphosis (PJK) (Kyphotic Cobb angle >15 degrees). This requires revision surgery that has been cited as up to 27% within 6 months following primary surgery. Osteoporotic vertebral compression fractures (VCFs) occur more often as the population becomes older. Prophylactic vertebroplasty (PVP) has been shown to provide benefit to patients with painful vertebral compression fractures in terms of both pain control and disability resolution. As cited in the previous study, the use of tapered cement dosage has been utilized in UIV (T10), UIV+1 (T9) and UIV+2 (T8) and instrumentation from T10-S1 which showed that there was no fracture at T7 (supra adjacent to the augmented vertebra). The tapered bone cement may buffer axial forces and allow a smoother load transfer through the segments [1]. In this study, various combination of tapered bone cement dosage along with different locations of the bone cement were simulated in an effort to obtain the optimal bone cement dosage and its location for the prophylactic vertebroplasty. Optimizing volume and location of cement within the vertebra may further reduce endplate stresses observed at the proximal junction above long instrumented deformity constructs, thereby further reducing the risk of fracture, PJK, and revision surgery.

METHODS: A validated FE model from T6 to pelvis (Figure 1) was used for the analyses. An osteoporotic model was developed and modified by insertion of screws and rods from T10 to S1, therein simulating the standard surgical procedure *in-silico*. The 9 different cases (Table 1) of tapered bone cement dosage were simulated in UIV (T10), UIV+1 (T9) and UIV+2 (T8) with the anterior, center and also the combination of anterior center location of bone cement. The load was applied to a metal bock 10 mm anterior to the center of the vertebra to simulate flexion moment and the pelvis was fixed (Figure 2). The stresses at the end plates of T7 to T10, as well as strains at the posterior ligaments were recorded to quantitatively evaluate the effect of different dosage and positions of bone cement.

RESULTS SECTION: Increasing dosages of cement (Cases 1 – 9) resulted in decreasing stresses at both the superior and inferior endplates of the cemented vertebra (T8, T9, and T10) (Figures 2 & 3) but resulted in increasing stress at the inferior endplate of T7. Although, anterior cement placement resulted in lower stresses observed in the superior and inferior endplates of the cemented T8, T9, and T10 vertebrae, compared to central placement, anterior placement resulted in a 4% increase in stress at the inferior endplate of T7. The % change in the stress between T7 inferior and T8 superior was lowest (30.8% for anterior(T8stress<T7stress) and -7.6%(T8stress>T7stress for center placement) for case 3 (T10-2.5cc, T9-2cc and T8-1cc). The combination of anterior and center placement (T10-Anterior, T9-Anterior central and T8-Center), resulted in low endplate stresses in both cemented (T10, T9, and T8) and non-cemented T7 vertebra.

DISCUSSION: The cement volume injected within the vertebra influenced endplate stresses. Increasing dosages of cement increased stiffness resulting in increased stress at the supra-adjacent unadulterated vertebra. The optimal cement dosage and location for this osteoporotic model (volume of T7=15.6cc, T8=17cc, T9=19.8cc and T10= 21.9cc) was T8-1cc (5.8%), T9- 2cc (10.1%) and 2.5cc (11.4%) when placed anteriorly at T10, anterior center at T9 and center at T8. The data of this study might be limited to this osteoporotic FE model as the patient vertebral body volume and osteoporosis may vary widely, thus might influence the optimal dosage and location for each individual patient.

SIGNIFICANCE: This study may contribute to the understanding of the optimum dosage and location of cement augmentation in the UIV of adult degenerative scoliosis patients to reduce PJF and PJK.

REFERENCES: 1. Zavatsky, J., Shah, A., McGuire, R., Serhan, H., Kelkar, A., Kodigudla, M., ... & Goel, V. (2016). Reduced Rate of Proximal Junctional Fractures Above Long-Segment Instrumented Constructs Utilizing a Tapered Dose of Bone Cement for Prophylactic Vertebroplasty- A Biomechanical Investigation. *Global Spine Journal*, *6*(S01), GO297.

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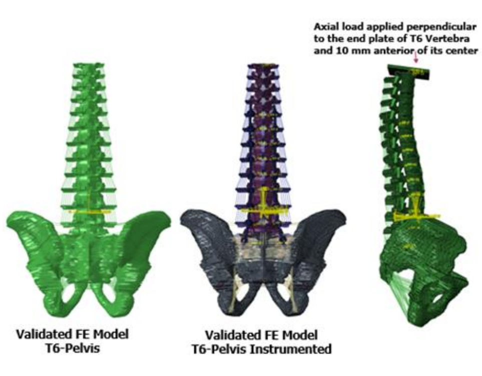

	Tapered Cement Dosage (cc)		
Case	T10	T9	T8
1	0	0	0
2	2	1.5	0.5
3	2.5	2	1
4	3	2.5	1.5
5	4	3	2
6	4	3.5	2.5
7	3	3	3
8	4.5	4	3
9	5	4	3.5

Figure 1: Validated FE model from T6-Pelvis **Figure 2**: Application of Load **Table 1**: Different cases of varying cement dosage