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Proximal Junctional Kyphosis Following Thoracolumbar Fusion Ending at the Lower Thoracic Spine: The Effect of Cement Augmentation

Rahul G Samtani[1*], **Anthony Ho**[2], **James Bernatz**[1], **Zachary Napier**[3] **and Joseph RO' Brien**[4]

[1]*Department of Orthopedic Surgery, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, USA*

[2]*Department of Orthopedic Surgery, Mid-Atlantic Permanent Medical Group, Springfield, Virginia, USA*

[3]*Department of Orthopedic Surgery, Cedars Sinai Medical Center, Los Angeles, California, USA*

[4]*Washington Spine and Scoliosis Institute, Bethesda, Maryland, USA*

[*]**Corresponding author:** Rahul G. Samtani, Department of Orthopedic Surgery, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, USA, Tel: +13015249903; E-mail: rsamtani@uwhealth.org

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Abstract

Study design: A retrospective comparative study.

Objective: The purpose of this study was to evaluate the role of cement augmentation in reducing the incidence of fractures and/or kyphosis at the proximal junction following treatment for adult thoracolumbar spinal deformity that ends at the lower thoracic spine.

Summary of background data: Proximal junctional kyphosis may occur due to ligamentous relaxation or fracture of the proximal vertebrae. The role of cement augmentation in preventing proximal junctional kyphosis or failure is unclear.

Methods: This study is a retrospective review of 25 patients who underwent >6 levels of instrumented fusion. Patients were divided into two groups according to whether or not they received cement augmentation at the upper instrumented vertebrae. All fusions had the lower thoracic spine as the cranial stopping point and S1 as the most caudal level.

Results: The mean age was 60.0 (range, 33-81), and the mean levels fused was 8.3 (range, 6-12). Average follow up was 20.4 months (range, 6-55). Six patients (24%) had acute proximal junctional kyphosis, two of whom did not receive cement augmentation and four of whom did. Of those patients, one was due to fracture in each group (P>0.05). However, the patient with cement and fracture leading to revision was not compliant with precautions due to delirium post operatively. Spinopelvic and regional spine measurements were statistically similar between the two groups.

Conclusion: Cement augmentation may prevent proximal junctional failure due to fracture, however, ligamentous proximal junctional kyphosis was seen in both the cemented and uncemented groups. Larger scale studies are required to further delineate the potential benefits of cement augmentation of the proximal aspect of thoracolumbar fusions stopping at the lower thoracic level.

Keywords: Proximal junctional kyphosis; Cement augmentation; Thoracolumbar fusion

Introduction

Spinal stabilization is indicated in a variety of adult spinal conditions to relieve pain, correct deformity, and prevent iatrogenic instability after neural decompression [1-7]. Proximal junctional kyphosis (PJK) has been a well described phenomenon in long segment instrumented fusions [1,8-10]. The factors predisposing to PJK deformity as well as the incidence of its occurrence have been well studied. Typically, PJK occurs within the first 6 months after surgery, however some authors have reported the importance of following patients for 5 years or more [11]. The incidence of PJK is highly variable and the etiology and preventive methods have not been clearly delineated yet. Older age, preoperative comorbidities, male sex, level of upper instrumented segment, and upper instrumented vertebral angle are some of the factors that have been postulated to contribute to PJK [3,8,12-14].

Many theories have been proposed as the causative etiology of PJK. One possible cause involves changes in the unfused mobile segments due to the increased stress transferred from the adjacent immobile fusion-so called modulus mismatch [15-23]. Breakdown at more proximal levels can have significant clinical implications with progressive deformity and pain, as well as possible catastrophic neurologic sequelae. Revision surgery may be required with more proximal extension of the fusion.

Proximal junctional kyphosis may occur via one of two mechanisms. The first mechanism is due to ligamentous failure, when the posterior stabilizing structures become insufficient and are unable to continue supporting the spine's structure (referred to as PJK). The second (and more pertinent to this paper) mechanism of failure may be due to vertebral fracture or implant failure at the site of the uppermost instrumented vertebra (UIV) or just proximal to it (proximal junctional failure or PJF). When this happens, collapse of the vertebral body results in subsequent kyphotic deformity. In a non-fusion setting, vertebroplasty has been shown to not only treat compression fractures also to prophylactically prevent collapse [24-26].

This study was designed to retrospectively evaluate the causes of PJK and PJF in long segment thoracolumbar fusions ending at the lower thoracic vertebrae within an adult population, as well as to investigate the potential role of cement augmentation at the UIV and UIV +1 in reducing fracture incidence.

Materials and Methods

Following Institutional Review Board approval, a retrospective review was conducted on 48 consecutive patients who received long-segment fusions from July 2007 to April 2012. All surgeries were performed at a single institution by one of two spine fellowship-trained surgeons. Inclusion criteria included age greater than 21, minimum follow up of 6 months, and a minimum of 6 levels of posterior instrumented fusion. Both primary and revision cases were evaluated. All patients required available pre and postoperative x-rays, clinical chart, and an operative summary.

Of the 48 patients evaluated, 25 patients were identified that met inclusion criteria. Five patients were excluded due to inadequate follow up, while 18 patients were excluded due to inadequate imaging (long standing films including the femoral heads). Clinical data collected included gender, age, weight, height, body mass index (BMI), previous spinal surgeries, preoperative diagnosis, operative summary, number of levels fused, osteotomy type, use of cement augmentation, and revision surgeries performed.

Radiographic measurement

Pre-operative and post-operative radiographic measurements were assessed. On lateral x-rays, proximal junctional (PJ) angles were measured with Cobb angles from the caudal endplate of the UIV to the cephalad endplate two vertebrae proximal to it. Proximal junctional kyphosis was identified if one the following occurred within 6 months of the index procedure: (1) The postoperative PJ angle was ≥ 10 degrees and at least 10 degrees greater than the preoperative measurement, as originally defined by Glattes et al. [8] or (2) proximal extension of the fusion was required or (3) a proximal vertebral fracture or implant failure was identified. Measurements were made utilizing Surgimap (Nemaris Inc, New York, NY, USA).

Regional spinal measurements included evaluation of the sagittal vertical axis (SVA), the perpendicular distance from the C7 plumb line to the posterior superior aspect of the S1 posterior superior endplate. Positive values indicated the line was anterior to the sacrum and negative values indicated that the line was posterior to the sacrum. Thoracic kyphosis (TK) was measured from the upper endplate of T5 to the lower endplate of T12, while thoracic lordosis (TL) was determined from the upper endplate of T10 to the lower endplate of L2. Lumbar lordosis was measured from the lower endplate of T12 to the upper endplate of S1.

Spinopelvic measurements included determination of the sacral slope (SS; angle between a horizontal line and the superior sacral endplate), pelvic tilt (PT, angle between the vertical and a line from the midpoint of the superior S1 endplate to the mid-axis of the femoral heads), and pelvic incidence (PI, angle between the perpendicular to the midpoint of the S1 superior endplate and a line from this point to the mid-axis of the femoral heads).

The patients were divided in two groups, based on whether or not they received cement augmentation. Group 1 consisted of fifteen patients who did not receive vertebroplasty of the UIV. Group 2 consisted of ten patients who did receive cement augmentation. In this group, open vertebroplasty was performed either at the UIV only, the UIV and the level just cephalad or caudal to it, or all three levels, as per surgeon preference. The procedure was performed via a transpedicular approach. Once all four walls of the pedicle were palpated and found to be intact, cannulas were utilized to inject 1 to 1.5 cubic centimeters of polymethyl methacrylate (PMMA) cement on either side of the vertebral body, under C-arm visualization. After waiting approximately eight minutes for the cement to appropriately cure, pedicle screws were then placed as necessary at their respective levels.

Statistical analysis was performed using Excel software. T tests were used to compare continuous variables between groups, while Fischer's exact test was used to evaluate categorical variables. P-values less than 0.05 were considered significant.

Results

In this retrospective review, 25 patients were included in this study. Fifteen (60%) of those patients were not cemented, while 10 (40%) patients were cemented. The majority of the patients underwent surgery for idiopathic or degenerative scoliosis. In the uncemented group, eight patients had degenerative scoliosis and three had idiopathic adult scoliosis. In the cemented group, eight patients had degenerative scoliosis while one had posttraumatic kyphosis.

Table 1 illustrates demographic information, surgical details, rate of PJK, and follow up outcomes. There were three males and 12 females in Group 1, with one male and nine females in Group 2. There were no significant differences in age, BMI, gender, previous spinal surgeries, levels fused, or number of anterior/posterior fusions (P>0.05). When considering follow up and outcomes, no significant difference was found between the length of follow up or the number of subsequent revisions needed (P>0.05).

Variables	All	Uncemented	Cemented	p value
	25	15	10	
Demographics				
Age (years)	60.04 (11.85)	56.67 (11.82)	65.10 (10.49)	0.13

BMI (kg/m^2)	29.05 (6.35)	28.70 (6.9)	29.52 (5.97)	0.78
Female	21 (84%)	12 (80%)	9 (90%)	0.63
Surgical details				
Primary	11 (44%)	7 (47%)	4 (40%)	1
Prior Revision	14 (56%)	8 (53%)	6 (60%)	1
Levels Fused	8.28 (1.65)	8.67 (1.95)	7.7 (0.82)	0.15
Anterior/Posterior	16 (64%)	9 (60%)	7 (70%)	0.69
Use of proximal hooks	8 (32%)	5 (33%)	3 (30%)	1
Mode of failure				
# of PJK failures	6 (24%)	2 (13%)	4 (40%)	0.18
Fracture	2 (8%)	1 (7%)	1 (10%)	1
Soft tissue	4 (16%)	1 (7%)	3 (30%)	0.27
Outcome				
Length of follow up (months)	20.4 (13.06)	20.67 (15.38)	20 (9.31)	0.9
Revised	6 (24%)	3 (20%)	3 (30%)	0.65
1Standard deviation in parenthesis				

Table 1: Demographics, surgical details, junctional failures, and outcomes.

In the uncemented group, two (13%) of the fifteen patients had junctional changes. One was due to a fracture (PJF, Figure 1), and one was due to ligamentous failure (PJK Figure 2). In the cemented group, four (40%) patients had junctional changes, one due to fracture (PJF Figure 3) and three due to ligamentous failure (PJK Figure 4). No significant difference was found between the rate or mode of failure between the two groups (P>0.05). Table 2 illustrates the levels cemented in relation to the UIV.

Patients	UIV	Cemented levels
1*	T10	T9/10
2	T10	T10
3	T10	T9/10
4*	T12	T12
5	T10	T9/10
6	T11	T11
7	T10	T9/10/11
8*	T10	T10/11
9	T9	T9/10
10*	T11	T10/11
*Denotes those with proximal junctional failure		

Table 2: Cement augmented levels.

Figure 1: Uncemented group, proximal junctional kyphosis due to a fracture.

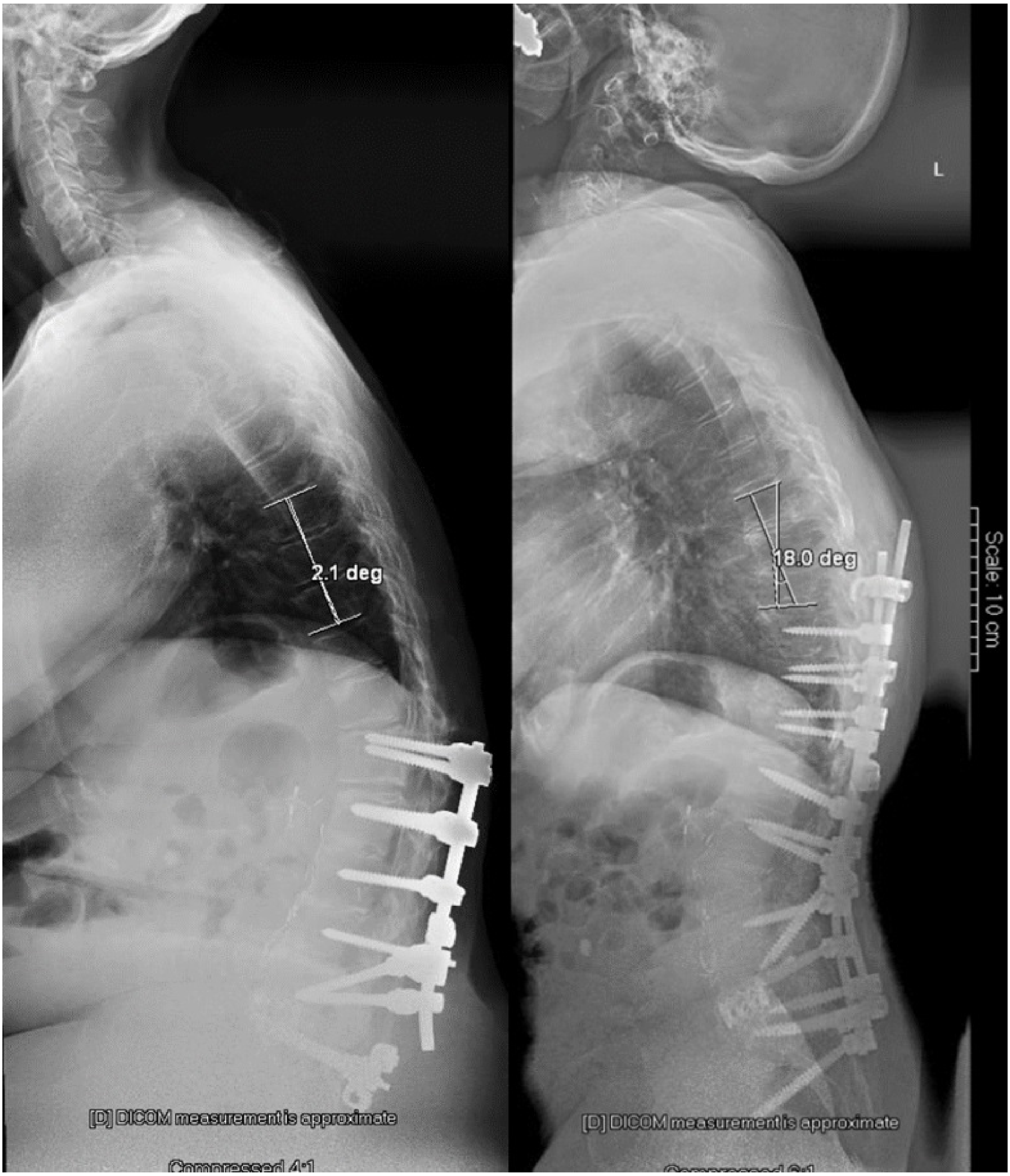

Figure 2: Uncemented group, proximal junctional kyphosis due to ligamentous failure.

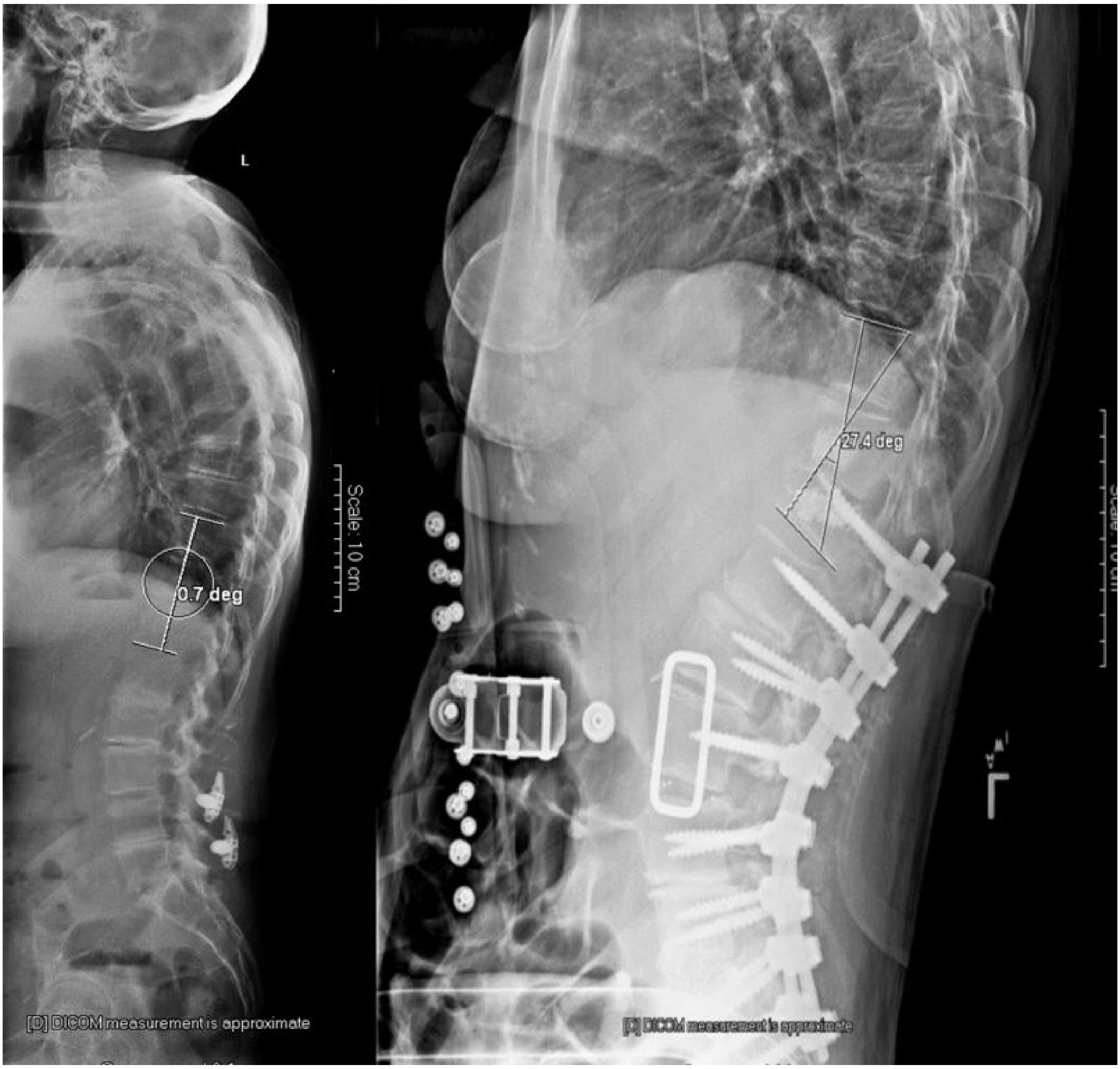

Figure 3: Cemented group, proximal junctional kyphosis due fracture.


L
3.5 deg
L
21.7 deg
[D] DICOM measurement is approximate

The pre-operative and postoperative spinopelvic measurements are shown in Table 3, as well as their respective changes. No significant differences were found between the uncemented and cemented groups in either preoperative or postoperative factors for all measured parameters (sacral slope, pelvic tilt, pelvic incidence). In addition, Table 4 shows regional spinal measurements, and their respective preoperative to postoperative changes. No significant differences were found between the groups for thoracic kyphosis, thoracic lordosis, lumbar lordosis, or sagittal vertical axis (P>0.05).

Variables	All	Uncemented	Cemented	p value
Pre-op				
Sacral slope (degrees)	30.75 (14.76)	33.5 (19.36)	28 (9.30)	0.54
Pelvic tilt (degrees)	24.33 (12.56)	23 (13.16)	25.67 (13.03)	0.73
Pelvic incidence (degrees)	55.67 (16.80)	57 (19.76)	54.33 (15.04)	0.8
Post-op				
Sacral slope (degrees)	34.67 (8.54)	36.67 (9.48)	32.67 (7.81)	0.44
Pelvic tilt (degrees)	21.42 (12.73)	18.17 (9.41)	24.67 (15.58)	0.4
Pelvic incidence (degrees)	56.25 (14.52)	55.17 (15.78)	57.33 (14.56)	0.81
Change (post-pre)				
Sacral slope (degrees)	3.92	3.17	4.67	
Pelvic tilt (degrees)	-2.91	-4.83	-1	
Pelvic incidence (degrees)	0.58	-1.83	3	
Based on 12 patients with complete pre-op and post-op measurements				

Table 3: Spinopelvic parameters.

Variables	All	Uncemented	Cemented	p value
Pre-op				
SVA (degrees)	7.36 (5.57)	5.36 (3.98)	8.68 (6.28)	0.28
TK (degrees)	22.38 (15.17)	13.5 (15.23)	28.33 (12.58)	0.06
TL (degrees)	9.61 (15.07)	5.01 (9.33)	12.67 (17.79)	0.35
LL (degrees)	34.8 (33.24)	44.67 (48.45)	28.22 (18.57)	0.37
Post-op				
SVA (degrees)	5.24 (4.13)	3.54 (2.26)	6.37 (4.81)	0.21
TK (degrees)	32.28 (13.67)	24 (10.88)	37.8 (12.93)	0.05
TL (degrees)	8 (7.74)	7.07 (9.28)	8.62 (7.06)	0.72
LL (degrees)	44.32 (6.89)	43.65 (5.72)	44.78 (7.87)	0.77
Change (post-pre)				
SVA (degrees)	-2.12	-1.82	-2.31	
TK (degrees)	9.9	10.5	9.47	
TL (degrees)	-1.62	2.06	-4.05	
LL (degrees)	9.52	-1.02	16.56	

Based on 15 patients with complete pre-op and post-op measurements

Table 4: Regional spinal alignment.

Discussion

Pedicle screw fixation has become widely used as the mode of treatment for long segment posterior fixation of the thoracolumbar spine. It provides numerous advantages compared with the more conventional hook and wire constructs, including 3 column fixation, decreased complication rates, and no need for any external orthoses [7,11,27,28]. Unfortunately, complications related to PJK/PJF can result in neurologic compromise with possible subsequent revision at high expense and morbidity. These failures may be due to accelerated degeneration from increased stress placed on adjacent levels above the rigid caudal segments [15-23]. Many causal factors have been investigated in prior studies, but all contributing risk factors have yet to be fully defined [2,3,8,11-14].

Many of the deformities that occur fail via fracture at the upper instrumented vertebra (a distinction from PJK cases that occur via ligamentous failure). In a long-term retrospective analysis, Yagi et al. [11] reported 24% of the PJK cases were due to fracture. Deformity through fracture may be most relevant when instrumentation ends in the thoracolumbar segment. In a multi-center study conducted by Hostin et al. [29], 47% of failures were due to fracture, with 66% of them occurring in the thoracolumbar region. Recently, Watanabe et al. [12] examined two groups of patients with proximal junctional fractures (PJF) after long segment pedicle fixation: those with failure at the upper instrumented level with adjacent vertebral subluxation and those with supra-adjacent vertebral collapse. They found that osteopenia, preoperative co-morbidities, severe preoperative sagittal imbalance, and old age were all associated with increased frequency of this complication.

Vertebral augmentation with cement has been shown to be effective in treating osteoporosis-related compression fractures, relieving pain as well as conferring increased mechanical strength [24-26]. Recent studies have also shown that it may have a role in reducing the risk of fractures prophylactically in a non-fusion setting. Kobayashi et al. [30] reported a significant decrease in new compression fractures in the supra-adjacent vertebrae to a fractured segment, from 22.4% to 9.7% in the first year when cement injection was used prophylactically. In addition, cement augmentation can improve initial screw fixation when pedicle screws are utilized [31]. These findings suggest a possible role for cement augmentation in reducing fracture incidence in PJK cases.

Conversely, a recent case report by Fernandez-Baillo et al. [32] suggests otherwise. They described a patient who underwent cement augmentation at the upper instrumented level as well as the supra-adjacent level during a T10 to pelvis posterior fusion. After the patient sustained a vertebral fracture at the upper instrumented level, the authors concluded that cement augmentation could in fact increase the rate of fracture due to: 1) pedicle weakening after screw insertion; 2) incomplete cement filling of the vertebra; and 3) inappropriate level selection for instrumentation at the cephalad level.

In the present study, we compared the rates of PJK after uncemented and cemented long segment fixation in the thoracolumbar spine. Six patients (24%) suffered PJK or PJF (two uncemented, four cemented). We did not find a significant difference in the incidence of junctional kyphosis or in the mode of failure between the groups (PJK versus PJF). However, when looking at the absolute numbers, one of two patients (50%) failed via fracture (PJF) in the uncemented group whereas one of four (25%) failed via fracture in the cemented group, though this association was not significantly different. It is important to note that the fracture failure in the cemented group was due to postoperative dementia requiring restraint placement. The patient trashed about in bed and fractured the upper vertebra and required revision. These numbers suggest that cement augmentation may protect against fracture but does not seem to protect against ligamentous failure (PJK) in long instrumented constructs.

Regardless of the mode of failure, bone mineral density studies should still be a routine part of the workup for patients undergoing long instrumented fusions in order to minimize fracture complications, as suggested by previous studies [8,12,12,33].

It should be emphasized that balancing the spinopelvic as well as regional spinal parameters is paramount in the prevention of PJK/PJF. Decreasing pelvic tilt, restoring sagittal balance, and properly ending the cephalad construct at the appropriate level all contribute to minimizing this complication. No significant differences were seen between cemented and uncemented groups, but correction of these factors would likely optimize patients' final outcomes [11,12,29,34].

Conclusion and Limitations

Much like many other studies investigating PJK, limitations of this study included a small sample size and short follow up. Many patients were lost prematurely in follow up or had to be excluded due to poor radiographic quality. This study is also limited by its retrospective nature. Finally, as stated previously, bone mineral density scores would be useful when considering insufficiency fractures associated with this complication.

Although this study did not demonstrate any statically significant etiology or preventative factors, further study is warranted to investigate the role of cement augmentation in decreasing PJK-related fractures in long segment spine fixation. Larger scale studies with long term follow up may provide additional information to further elucidate its potential benefits.

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