Biomechanics of Topping-off the Fused Segment

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Background

Lumbar fusions have increased due to the positive results in the patients of severe low back pain. The long term follow ups have shown the prevalence of adjacent segment disease (ASD) following the lumbar fusion. As reported in the literature, the ASD incidences in radiography are from 8-100 % and in symptomatology are 5.2-18.5% [1]. The best management of the ASD has been a historical dilemma. One of the reason for ASD is the transition of loads from fused to the non-fused segment in the spine that creates a stiff vertebra and increased stresses at the discs of the adjacent level. Dynamic devices have shown success in the smoother load transition in the spine [2,3]. This study investigates the biomechanics of combination of fusion and non-fusion devices that may help in reducing ASD by providing a topping off to the fused segment.

Aims

The main hypothesis of this study is the use of the non-fusion devices at the proximal and distal adjacent levels to the fused segment may produce a tapered increase in motion at the adjacent levels as opposed to the sudden increase and lowers the stresses at the adjacent levels.

Methods

A validated finite element model from L1 to Pelvis was used for this study. The model was developed from the CT scans of a healthy adult spine and the material properties were assigned based on the literature (Appendix 1).

Three groups were evaluated in this study:

Group 1 (Control Group): Pedicle screw instrumentation at L3-L4 (Figure 1),

Group 2: Pedicle screw instrumentation at L3-L4 with the dynamic stabilization using interspinous (coflex) at the adjacent levels (proximal (L2-L3) and both-proximal and distal (L2-L3 and L3-L4)) (Figure 2)

Group 3: Pedicle screw instrumentation at L3-L4 with flexible rods at the adjacent levels (proximal (L2-L3) and both-proximal and distal (L2-L3 and L3-L4)) (Figure 3)

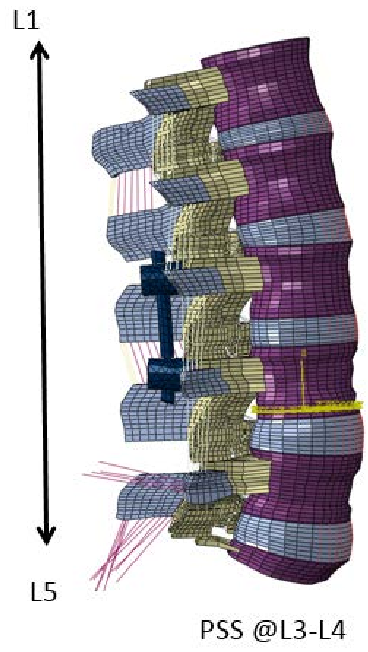

Figure 1: Pedicle screw system at L3-L4

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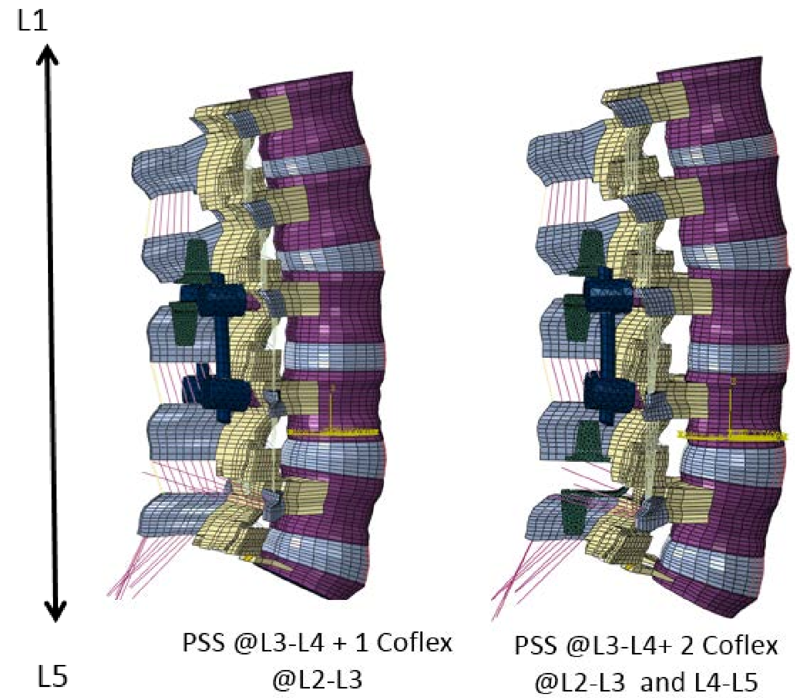

Figure 2: Pedicle screw system at L3-L4 with coflex at 1 level and at 2 levels

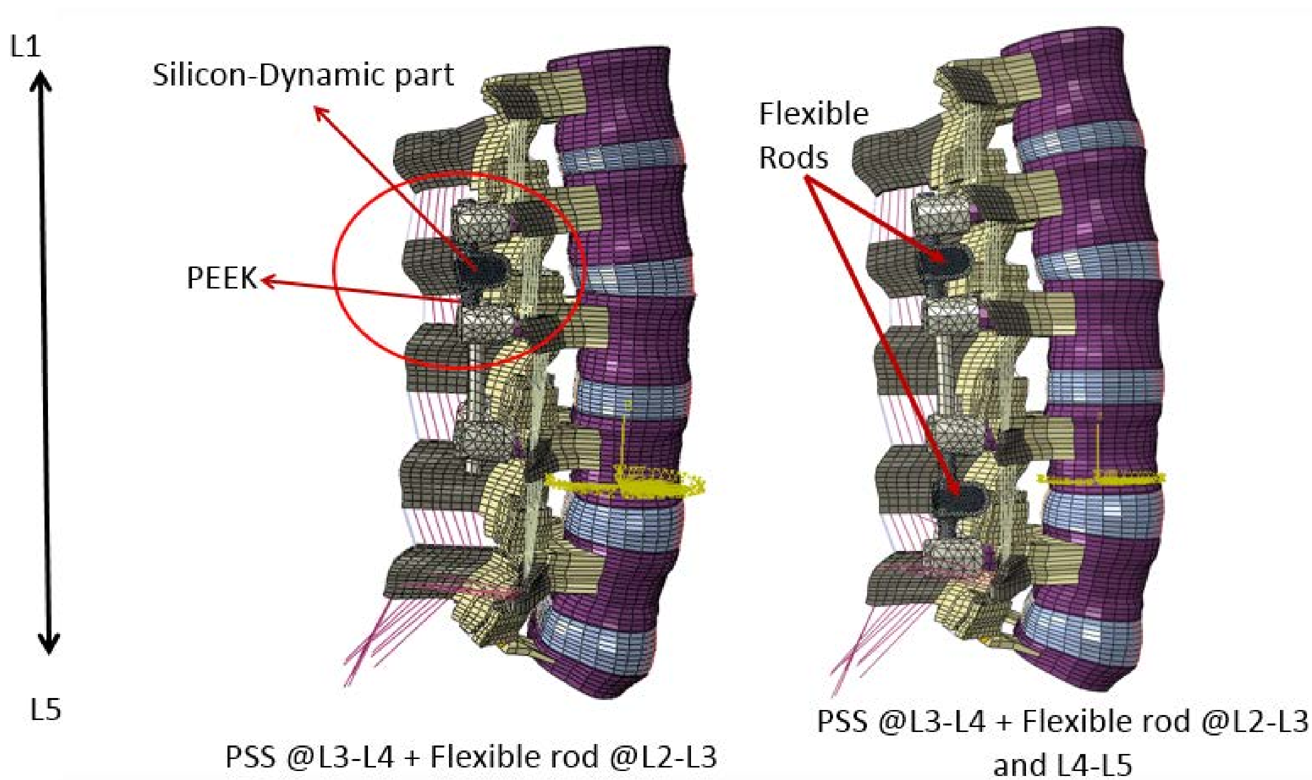

Figure 3: Pedicle screw system at L3-L4 with flexible rods at 1 level and at 2 levels

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The 400 N follower load was simulated along with 10 Nm moments, applied at L1 to simulated flexion, extension, lateral bendings and axial rotations. All the models were simulated for normal discs, Type 1 degenerated discs and Type 2 degenerated discs.

For the simulation of the implantation of interspinous (coflex), the interspinous processes were distracted by 2 mm and then the coflex was placed in the models. The stresses at the anterior annulus, posterior annulus and nucleus were evaluated and compared with all the cases.

Results

The results showed that the stresses on the discs for L1-L2, L3-L4 and L5-S1 were similar for all the groups (shown for extension in Table 1). The stresses at the discs were first compared between the dynamic devices implanted at the proximal levels and the percentage change in the stresses were evaluated (Tables 2- 4). Secondly, the percentage change in the stresses at the discs were evaluated and compared between the dynamic devices implanted at the proximal and distal levels (Tables 4-10).

Table 1: Intradiscal pressures and stresses at the discs for Extension

L1-L2			
	Ant Annulus	**Pos Annulus**	**IDP**
PSS @L3-L4	**1.432**	**3.96**	**0.27**
PSS+Flexible Rods @L2-L3	**1.44**	**3.97**	**0.266**
PSS+ Coflex @L2-L3	**1.443**	**3.878**	**0.2637**

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L2-L3			
	Ant Annulus	**Pos Annulus**	**IDP**
PSS @L3-L4	**1.386**	**5.413**	**0.317**
PSS+Flexible Rods@L2-L3	**0.117**	**0.214**	**0.023**
PSS+ Coflex @L2-L3	**0.4848**	**0.95**	**0.09458**
L3-L4			
	Ant Annulus	**Pos Annulus**	**IDP**
PSS @L3-L4	**0.25**	**0.26**	**0.028**
PSS+Flexible Rods@L2-L3	**0.2716**	**0.287**	**0.034**
PSS+ Coflex @L2-L3	**0.2639**	**0.26**	**0.033**
L4-L5			
	Ant Annulus	**Pos Annulus**	**IDP**
PSS @L3-L4	**0.536**	**1.282**	**0.109**
PSS+Flexible Rods@L2-L3	**0.548**	**1.35**	**0.113**
PSS+ Coflex @L2-L3	**0.5348**	**1.28**	**0.1089**
L5-S1			
	Ant Annulus	**Pos Annulus**	**IDP**
PSS @L3-L4	**0.536**	**1.282**	**0.109**
PSS+Flexible Rods@L2-L3	**0.548**	**1.35**	**0.113**
PSS+ Coflex @L2-L3	**0.5348**	**1.28**	**0.1089**

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Table 2: % Decrease in the Intradiscal pressures w.r.t. PSS for L2-L3 disc		
	PSS+ Flex Rod @L2-L3	PSS+ Coflex @L2-L3
Extension	93%	71.6%
Flexion	63.7%	48.27%
Left Bending	66%	7.5%
Right Bending	66.5%	8%
Left Rotation	51.5%	1%
Right Rotation	42.2	4.4%

Table 3: % Decrease in the stresses at the Anterior annulus w.r.t. PSS for L2-L3 disc		
	PSS+ Flex Rod @L2-L3	PSS+ Coflex @L2-L3
Extension	91.5%	65%
Flexion	69%	46.5%
Left Bending	81%	43.5%
Right Bending	81.2%	43.5%

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Left Rotation	59.4%	1.8%
Right Rotation	55.2%	4.3%

Table 4: % Decrease in the Posterior annulus stresses w.r.t. PSS for L2-L3 disc		
	PSS+ Flex Rod @L2-L3	PSS+ Coflex @L2-L3
Extension	96%	82.4%
Flexion	57.1%	70.2%
Left Bending	72.6%	37.65
Right Bending	70.2%	32%
Left Rotation	63.4%	36%
Right Rotation	55%	36.5%

Table 5: % Decrease in the intra discal pressures (IDP) w.r.t. PSS for L2-L3 disc		
	PSS+ Flex Rod @L2-L3 & L4-L5	PSS+ Coflex @L2-L3 & L4-L5
Extension	93.4	66.13
Flexion	70.7	56.6
Left Bending	71.5	15
Right Bending	72.5	14

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Left Rotation	60.5	13
Right Rotation	52.3	14

Table 6: % Decrease in the stresses at the Anterior annulus w.r.t. PSS for L2-L3 disc

	PSS+ Flex Rod @L2-L3 & L4-L5	PSS+ Coflex @L2-L3 & L4-L5
Extension	91.5	69.4
Flexion	72.7	47.4
Left Bending	81.5	40.15
Right Bending	82.7	39.6
Left Rotation	63.4	1
Right Rotation	57.45	1.3

Table 7: % Decrease in the stresses at the Posterior annulus w.r.t. PSS for L2-L3 disc

	PSS+ Flex Rod @L2-L3 & L4-L5	PSS+ Coflex @L2-L3 & L4-L5
Extension	96.1	90.2
Flexion	63.3	76.7
Left Bending	76.5	41.9
Right Bending	74.6	39.6

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Left Rotation	67.6	30.6
Right Rotation	61.2	31.94

Table 8: % Decrease in the intra discal pressures (IDP) w.r.t. PSS for L4-L5 disc

	PSS+ Flex Rod @L2-L3 & L4-L5	PSS+ Coflex @L2-L3 & L4-L5
Extension	75	55
Flexion	57.8	30.5
Left Bending	62.06	17.24
Right Bending	61.6	22.6
Left Rotation	27.1	2.7
Right Rotation	19.8	3.12

Table 9: % Decrease in the stresses at the Anterior annulus w.r.t. PSS for L4-L5 disc

	PSS+ Flex Rod @L2-L3 & L4-L5	**PSS+ Coflex @L2-L3 & L4-L5**
Extension	58.96	26.12
Flexion	57.9	27
Left Bending	63.8	26.21

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Right Bending	62.65	29.4
Left Rotation	30.2	8
Right Rotation	26.9	7.7

Table 10: % Decrease in the stresses at the Posterior annulus w.r.t. PSS for L4-L5 disc

	PSS+ Flex Rod @L2-L3 & L4-L5	PSS+ Coflex @L2-L3 & L4-L5
Extension	80.4	70.8
Flexion	28.6	58.7
Left Bending	62.6	31.4
Right Bending	60.2	37.33
Left Rotation	27.9	18.6
Right Rotation	21.2	17.3

The intradiscal pressures were similar for the type 1 and type 2 disc degeneration, as both were mildly degenerated discs with the loss of incompressibility of the nucleus. There was a higher reduction of the stresses with the flexible rods implanted at the proximal (L2-L3) and distal (L4-L5) levels compared to the implantation of interspinous (coflex). The stresses at the posterior annulus of proximal and distal levels were higher with the implantation of flexible rods only for flexion.

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Discussion and Conclusions

Intradiscal pressures and the stresses at the annulus reduced with the implantation of flexible rods and coflex at the proximal and distal junction for all the motions. However, there was a higher reduction of the stresses with the flexible rods implanted at the proximal level compared to the implantation of interspinous (coflex). This may be due to the higher stability provided by the flexible rods compared to the interspinous (coflex) leading to the decrease in the stresses at the intervertebral disc. According to the literature [4], the interspinous devices mainly limits extension and flexible rods limits flexion. From the results, for the flexion, the stresses only at the posterior annulus where higher for the flexible rods which may be the result of the surgical procedure involving the distraction of the interspinous processes before the implantation of coflex. These dynamic systems provided the topping off the fused segment and allowed a gradual load transition through the proximal and distal levels, providing a better outcome. This may lead to the decrease in the adjacent segment diseases, which may help in the reduction of proximal junction kyphosis (PJK) and distal junction kyphosis (DJK).

References

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