



Biomechanical analysis of Instrumented decompression and Interbody fusion procedures in Lumbar spine: a finite element analysis study

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Abstract

Interbody fusions have become increasingly popular to achieve good fusion rates. Also, unilateral instrumentation is favored to minimize soft tissue injury with limited hardware. Limited finite element studies are available in the literature to validate these clinical implications. A three-dimensional, non-linear ligamentous attachment finite element model of L3-L4 was created and validated. The intact L3-L4 model was modified to simulate procedures like laminectomy with bilateral pedicle screw Instrumentation, transforaminal, and posterior lumbar interbody fusion (TLIF and PLIF, respectively) with unilateral and bilateral pedicle screw instrumentation. Compared to instrumented laminectomy, interbody procedures showed a considerable reduction in range of motion (RoM) in extension and torsion (6% and 12% difference, respectively). Both TLIF and PLIF showed comparable RoM in all movements with < 5% difference in reduction of RoM between them. Bilateral instrumentation showed a more significant decrease in RoM (> 5% difference) in the entire range of motion except in torsion when compared to unilateral instrumentation. The maximum difference in reduction in RoM was noted in lateral bending (24% and 26% for PLIF and TLIF, respectively), while the least difference in Left torsion (0.6% and 3.6% for PLIF and TLIF, respectively) in comparing bilateral with unilateral instrumentation. Interbody fusion procedures were found to be biomechanically more stable in extension and torsion than the instrumented laminectomy. Single-level TLIF and PLIF achieved a similar reduction in RoM with a < 5% difference. Bilateral screw fixation proved biomechanically superior to unilateral fixation in the entire range of motion except in torsion.

Keywords Spine biomechanics · Lumbar spine · Finite element method · Posterior lumbar interbody fusion · Transforaminal lumbar interbody fusion · Pedicle screws

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1 Introduction

Lumbar degenerative spine disease (DSD) accounts for a significant disability globally, affecting about 3.6% of the global population [1]. It is a spectrum of conditions that includes disc degeneration, lumbar spinal stenosis, and spondylolisthesis. Patients with failed conservative management require surgical procedures to relieve pain due to lumbar spondylosis. Fusion procedures have become the treatment of choice for many years for treating back pain due to DSD, yet high-level evidence of the best surgical strategy is lacking so far [2]. Interbody fusions have become increasingly popular with the primary aim to achieve better decompression and reasonable fusion rates. Studies have compared the results of posterolateral fusions with interbody fusions in DSD to show no difference in clinical outcomes between the two procedures [3–5]. Various techniques of interbody fusions have evolved; Posterior and Transforaminal Lumbar Interbody Fusion (PLIF and TLIF, respectively) are commonly used [6]. Clinical studies suggest that TLIF and PLIF could achieve similar clinical outcomes and fusion rates in degenerative lumbar diseases. However, TLIF has the advantage over PLIF in reducing the complication rate, operative time, and blood loss during surgery [7, 8]. On the other hand, biomechanical studies [9–11] have shown conflicting results regarding the superiority of one technique over another.

There is an increasing trend of interbody fusions with unilateral pedicle screw fixation with the advantage of minimal soft tissue injury, limited hardware, and morbidity related to the approach. Clinical studies showed no difference between unilateral vs. bilateral instrumentation with TLIF in terms of clinical outcomes and fusion rates in short-term follow-ups [12, 13]. Long-term follow-up studies are yet to be done to adapt unilateral instrumentation with TLIF as an alternative to bilateral instrumentation. The finite element analysis (FEA) literature comparing unilateral with bilateral instrumentation in PLIF/TLIF is sparse and some studies suggest the superiority of bilateral instrumentation [14–16].

In this regard, biomechanical analysis can provide important insight into all these conflicting observations. Finite element analysis is one of the best methods to decrease subject-related variability and create an idealized spine model [17]. Therefore, this study analyzes and compares the biomechanics of instrumented laminectomy, TLIF, and PLIF with unilateral and bilateral pedicle screw fixation using a finite element (FE) model. The current study is novel because it aims to compare decompression fusion surgeries with/without interbody cages and analyze the effect of unilateral and bilateral instrumentation in interbody fusion surgeries. Additionally, high-fidelity

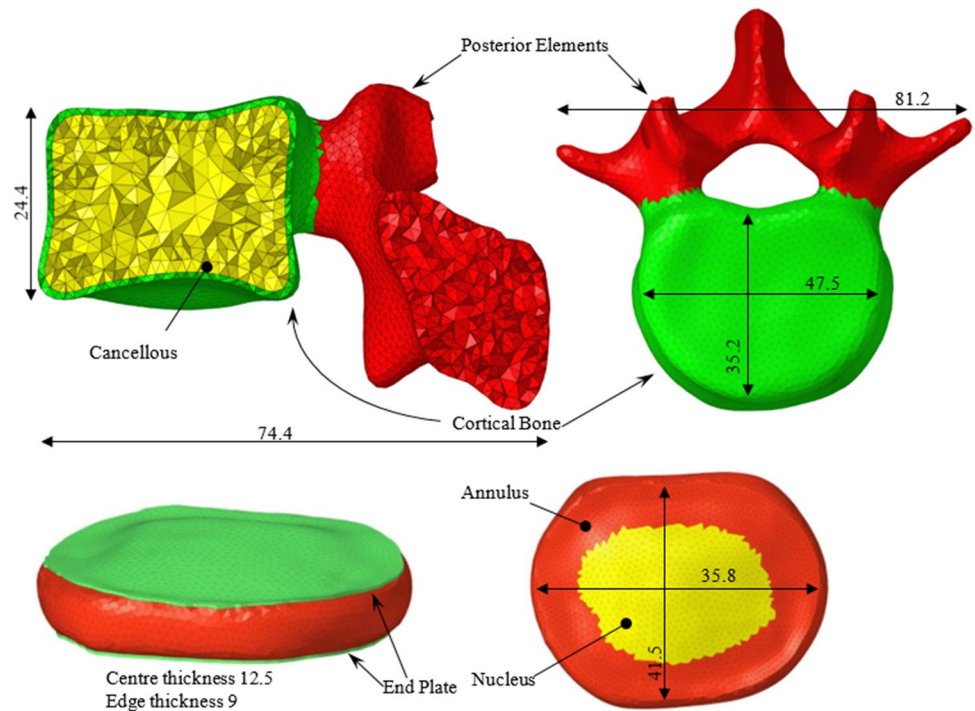
surgical modifications were carried out on the FE model to mimic the actual procedures accurately. For the study, anatomically partitioned models and non-linear ligaments are used. Anatomical partitioning refers to partitioning the FE model into different regions based on actual anatomy. For example, the vertebra is partitioned into three parts, namely, cortical and cancellous bones and posterior elements.

2 Methods

2.1 FE model of intact lumbar functional spine unit

A three-dimensional, non-linear ligamentous attachment FE model of the L3-L4 functional spine unit (FSU) was created from a Computed Tomography (CT) scan of a healthy male of 30 years old. The slice thickness of 1.5 mm was considered to create the FE model. Commercially available and open-sourced software was used for generating surface models of the required body part from the CT scan data (3DSlicer 4.10.0), developing solid models from the generated surface models, partitioning of solid models according to the anatomy of the required region (ANSYS Spaceclaim 19.0), assigning material properties to solid model and its discretization into the finite elements (Hypermesh 2017), assembly of the discretized model followed by application of loads, boundary conditions and interactions and FE simulation for displacement field and stress field (Abaqus 6.13). Both L3 and L4 vertebra were recreated to mimic the anatomy, consisting of the cortical bone outer shell of 1 mm thick enclosing a cancellous core, and the vertebral arch was modeled as posterior elements as shown in Fig. 1. The intervertebral disc was created with nucleus pulposus and annulus fibrosus (as presented in Fig. 1), along with the cartilaginous endplates (at superior and inferior surfaces) of 0.5 mm thick. In the FE model, cancellous bone, cortical bone, posterior elements, annulus fibrosus, and nucleus pulposus were discretized by tetrahedral elements (C3D4), while endplates were discretized with wedge elements (C3D6). The vertebra (L3/L4) and disc have about 75,000 and 57,000 elements. The screws and rods were modeled using approximately 40,000 and 17,000 C3D4 elements. Articular surfaces of facet joints were joined by surface to surface friction contact (coefficient of friction = 0.1). The vertebral body was attached to the disc by tie constraints. All the seven ligaments of the motion segment were modeled using the connectors (axial spring type with tension connector behavior). The ligamentous structure of the motion segment consisted of seven different ligaments, viz. anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flavum

Fig. 1 The FE model of the vertebra and intervertebral disc along with anatomy (dimensions are in mm)



(LF), interspinous ligament (ISL), supraspinous ligament (SSL), intertransverse ligament (TL), and capsular ligament (CL). The orientation and length of ligaments (origin and insertion) were determined using anatomical data from the literature [18–20] and defined in the model by choosing the nodes in that region, as shown in Fig. 2. The number of connectors defined the thickness of the ligament. The material properties of the various components of the FSU were derived from the literature [18, 20, 21], as shown in Table 1. In the FE model, the stiffness of the ligaments is calibrated from the literature data according to the length of the ligaments.

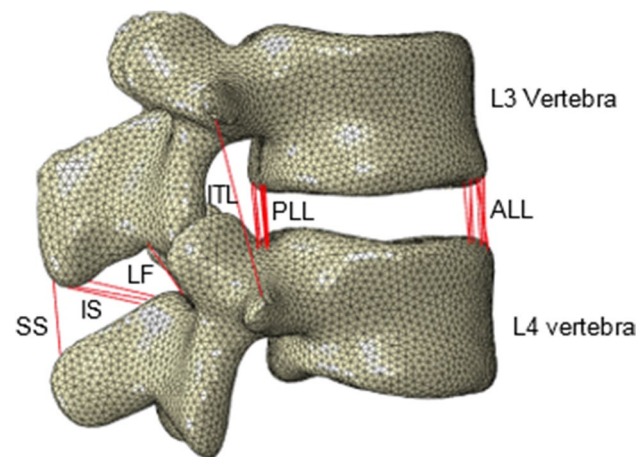


Fig. 2 A schematic figure showing vertebrae and ligaments of the L3-L4 segment

2.2 Boundary and loading conditions

The bottom surface of the L4 vertebra was fixed in all degrees of freedom and a pure moment of 10 Nm was applied in the direction of motion on the top surface of the L3 vertebra to represent movements of flexion/extension, lateral bending, and axial rotation as shown in Fig. 3. The intervertebral disc constrained with the vertebrae and ligaments were defined by the connectors. The surface interactions were defined between the connected surfaces of instrumentation and vertebrae. The obtained angles from the simulated loading were computed and analyzed in the presented study.

2.3 Modeling of implants

The intact solid model of L3-L4 was modified to simulate different decompressive lumbar procedures like Laminectomy with Bilateral Pedicle Screw Instrumentation (LM + BPS), TLIF with Unilateral, and Bilateral Pedicle Screw instrumentation (TL + UPS/TL + BPS), PLIF with Unilateral and Bilateral Pedicle Screw instrumentation (PL + UPS/PL + BPS). All the FE models after decompression procedures are shown in Fig. 4. The implants, i.e., rods of the diameter of 5.5 mm, pedicle screws of $\phi 6.5 \times 50$ mm (L3), and $\phi 7.0 \times 50$ mm (L4), as shown in Fig. 5, were used in the surgical procedures. The connection between FE models of vertebrae and pedicle screw was connected with tie constraints working as bonded connections. The implants were considered of biocompatible

Table 1 The material properties used for the simulations

Material	Properties	
Vertebra	Young's Modulus (MPa)	Poisson Ratio
Cortical Bone	12000	0.3
Cancellous Bone	100	0.2
Posterior Elements	3500	0.25
Disc		
Nucleus	1	0.499
Annulus	4.2	0.45
Endplates	24	0.4
Instrumentation		
Pedicle Screw	105000	0.31
Rods	105000	0.31
PEEK cage	3400	0.4
Ligaments	Stiffness (N/mm)	Strain (%)
Anterior Longitudinal Ligament	347	0 – 12.2
	787	12.2 – 20.3
	1864	> 20.3
Interspinalis Ligament	1.4	0 – 13.9
	1.5	13.9 – 20.0
	14.7	> 20.0
Capsular Ligament	36	0 – 25.0
	159	25.0 – 30.0
	384	> 30.0
Intertransversalis Ligament	0.3	0 – 18.2
	1.8	18.2 – 23.3
	10.7	> 23.3
Ligamentum flavum	7.7	0 – 5.9
	9.6	5.9 – 49.0
	58.2	> 49.0
Posterior longitudinal Ligament	29.5	0 – 11.1
	61.7	11.1 – 23.0
	236	> 23.0
Supraspinatus Ligament	2.5	0 – 20.0
	5.3	20.0 – 25.0
	34	> 25.0

titanium alloy, whose material properties are tabulated in Table 1. The implants' positioning and the tissues' removal from the models were supervised by expert surgeons and explained as follows.

3 LM + BPS

The lamina and spinous process of the L3 vertebra, supraspinous ligament, interspinous ligament, and ligamentum flavum were removed to mimic the laminectomy procedure. Screw holes were created in the pedicles on bilateral sides to incorporate the pedicle screws ($\phi 6.5 \times 50$ mm (L3) and $\phi 7.0 \times 50$ mm (L4)) in the vertebrae, and interconnecting rods of appropriate size ($\phi 5.5$ mm \times 80 mm) were modeled to mimic bilateral pedicle screw instrumentation.

4 TL + UPS/TL + BPS

The left side facet joints, facet joint capsule, ligamentum flavum, and posterolateral part of the intervertebral disc were removed. The PEEK (Polyetheretherketone) cage of size (24 mm \times 12 mm \times 10 mm) was inserted (in the nucleus pulposus region) obliquely midway in both sagittal and coronal planes between the L3-L4 vertebrae to mimic the TLIF procedure. Screw holes were created in the pedicles on unilateral or bilateral sides to incorporate the pedicle screws ($\phi 6.5 \times 50$ mm (L3) and $\phi 7.0 \times 50$ mm (L4)) in the vertebrae, and interconnecting rods of appropriate size ($\phi 5.5$ mm \times 80 mm) were modeled to mimic unilateral or bilateral pedicle screw instrumentation.

5 PL + UPS/PL + BPS

The lamina of the L3 vertebra, supraspinous ligament, interspinous ligament, ligamentum flavum, and part of the intervertebral disc were removed. The PEEK cage of size (24 mm \times 12 mm \times 10 mm) was inserted between the L3-L4 vertebrae to mimic the PLIF procedure. The screw holes were created in the pedicles on unilateral or bilateral sides to incorporate the pedicle screws ($\phi 6.5 \times 50$ mm (L3) and $\phi 7.0 \times 50$ mm (L4)) in the vertebrae, and interconnecting rods of appropriate size ($\phi 5.5$ mm \times 80 mm) was modeled to mimic unilateral or bilateral pedicle screw instrumentation.

The surface interactions were defined between the connected surfaces of instrumentation and vertebrae. The modified models were imported to the HyperMesh and converted to the FE mesh model. The anatomical material properties were assigned and models were subjected to loading the same as intact cases.

6 Results

6.1 Validation of the intact FE model

The Intact L3-L4 FE model was validated against the experimental cadaveric study performed by Yamamoto et al. [22] in terms of angular displacement. Additionally, results from a numerical analysis by Zander et al. [23] were also used to validate the results from the present study. A slight difference in the results of the present study and reference studies indicates that the actual material and material properties of the cadaveric and numerical analysis may have differed from the present study. However, it is noted that, despite the unavoidable variation in results, the material properties used in the present study accurately capture the experimentally

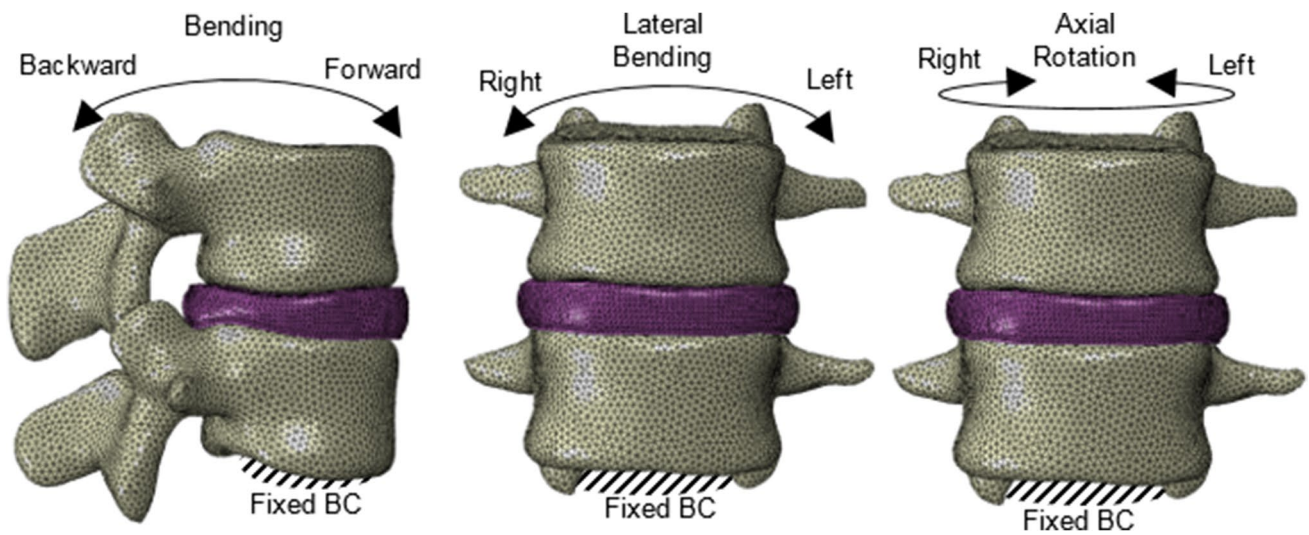


Fig. 3 A schematic representation of the applied loads and boundary conditions on the L3-L4 motion segment

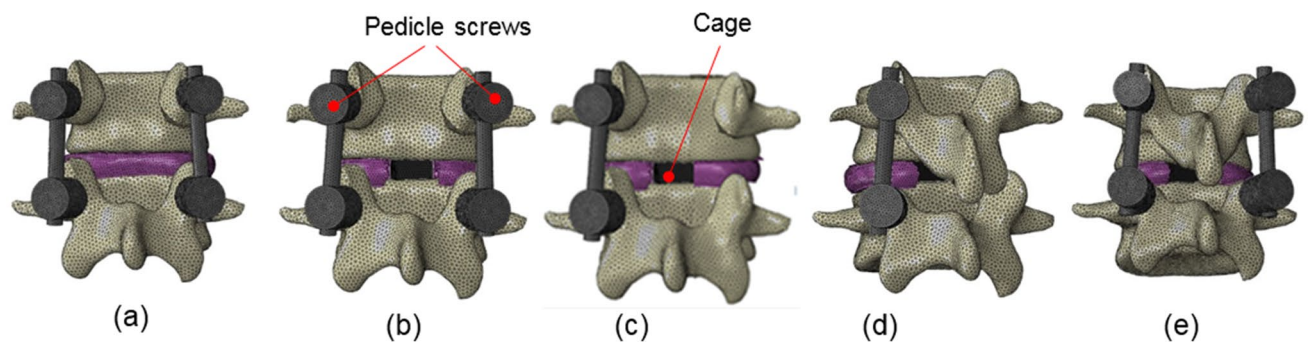
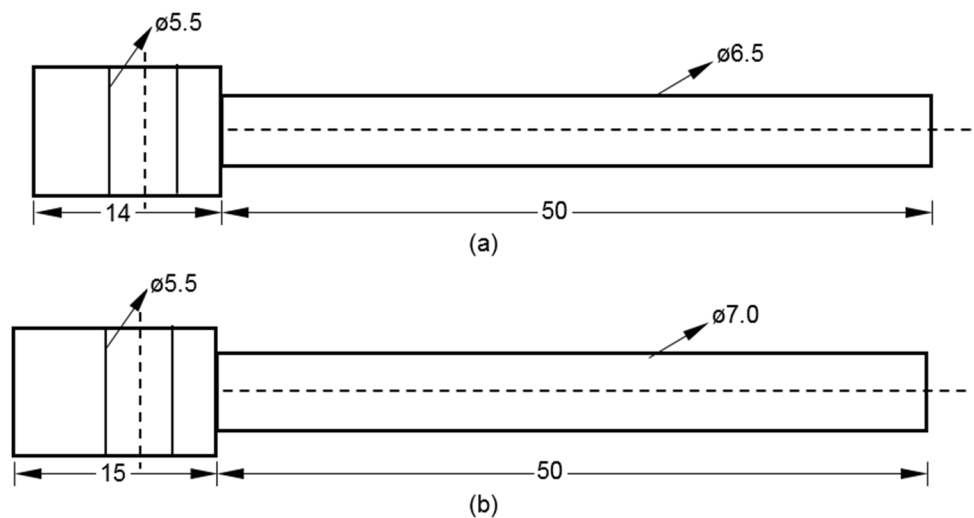


Fig. 4 The modified FE models showing (a) LM+BPS, (b) PL+BPS, (c) PL+UPS, (d) TL+UPS, (e) TL+BPS. LM+BPS – Laminectomy with Bilateral pedicle screw fixation. PL+BPS—PLIF with Bilateral pedicle screw fixation. PL+UPS—PLIF with Unilateral pedicle screw fixation. TL+UPS—TLIF with Unilateral pedicle screw fixation. TL+BPS—TLIF with Bilateral pedicle screw fixation

Fig. 5 The schematic of the pedicle screws used in decompression procedures for (a) L3 vertebra, (b) L4 vertebra (dimensions are in mm)



and numerically observed trend in the results. After loading the top surface of L3 vertebrae with 10 Nm in all directions of freedom, the simulation results were presented as contour plots of displacement and stress obtained from Abaqus software. The dot product of two-position vectors at the top of the model was used to compute the angular displacement. The values of RoM in all the motions were calculated (Table 2), which were found to be in good agreement with the experimental results [22] (Fig. 6). The RoMs in all the motions were found within the acceptable range of the initial model (Fig. 6). Hence, the initial FE model was considered a basic model for decompression procedures. The deformed displacement contour plots of the FE model in all motions are shown in Fig. 7.

6.2 Range of motion (RoM) of modified FE models

The obtained angles from the simulations are presented in Table 3. The percentage reduction in RoM was calculated using the following relation and is tabulated in Table 3.

$$\% \text{ reduction} = \frac{|RoM_{\text{intact}} - RoM_{\text{surgery}}|}{RoM_{\text{intact}}} \times 100 \quad (1)$$

The percentage reduction in different decompression procedures is compared and the difference of more than 5% in RoM reduction in decompression procedures is considered significant.

6.3 RoM reduction in Instrumented Laminectomy (LM + BPS) compared to Interbody procedures (PL + BPS and TL + BPS)

The comparison of the instrumented laminectomy (LM + BPS) and interbody fusion procedures (PL + BPS, TL + BPS) shows a significant reduction in extension and torsion RoM (6% and 12% difference, respectively). In comparison, a slight difference was observed in the reduction in RoM (<5% difference) in flexion and bending (Fig. 8a).

Table 2 Range of motion in all the motions of intact FE model

Motion	Range of Motion (degrees)
Flexion	6.89
Extension	3.59
Right lateral bending	4.11
Left lateral bending	4.07
Right Torsion	2.67
Left Torsion	2.74

Both Instrumented laminectomy and interbody procedures showed a large reduction in RoM in flexion.

6.4 RoM reduction with PLIF compared to TLIF (on comparing with similar instrumented states)

PLIF and TLIF showed comparable RoM in all motions, with less than a 5% difference in the reduction of RoM between them.

6.5 ROM reduction with Unilateral instrumentation compared to bilateral instrumentation

PL + BPS and TL + BPS showed a more significant reduction in RoM (>5% difference) in all motions except in torsion compared to PL + UPS and TL + UPS, respectively. The maximum difference in reduction in RoM was noted in lateral bending (24% and 26% for PLIF and TLIF, respectively), while the slightest difference in left torsion (0.6% and 3.6% for PLIF and TLIF, respectively) in comparing bilateral with unilateral instrumentation (Fig. 8b).

7 Discussion

The selection of appropriate surgical techniques, implants, and instrumentation in treating lumbar degenerative spine disease has always been debated. Differences in the results of clinical and biomechanical studies further make the situation difficult. These differences can be resolved by conducting an FEA study to analyze the biomechanical properties of different surgical techniques in lumbar decompression surgery. In the current study, an intact FE model of L3-L4 FSU is validated against previous cadaveric studies in the literature [22] and modified FE models were used to mimic instrumented laminectomy, PLIF, and TLIF with unilateral/bilateral pedicle screw fixation. The presented study is more accurate in terms of FE analysis, as the anatomically partitioned model with non-linear ligaments is used. In addition, accurate surgical modifications were carried out on the FE model to mimic the decompression procedures.

Yadav et al. [3], Hoy et al. [4], and Zhang et al. [5] compared Posterolateral fusion (PLF) with TLIF and reported no difference in clinical outcomes in patients with degenerative spine disease. Farrokhi et al. [24], in a prospective study on 88 patients with lumbar spinal stenosis, concluded that PLF with posterior instrumentation provides better clinical and functional outcomes, despite the low fusion rates compared to PLIF. Yijian et al. [25] compared PLF and PLIF in a study on 72 patients with degenerative spondylolisthesis and found that PLIF can achieve better restoration of spinopelvic sagittal balance parameters and PLIF has less incidence of postoperative chronic low back pain than PLF.

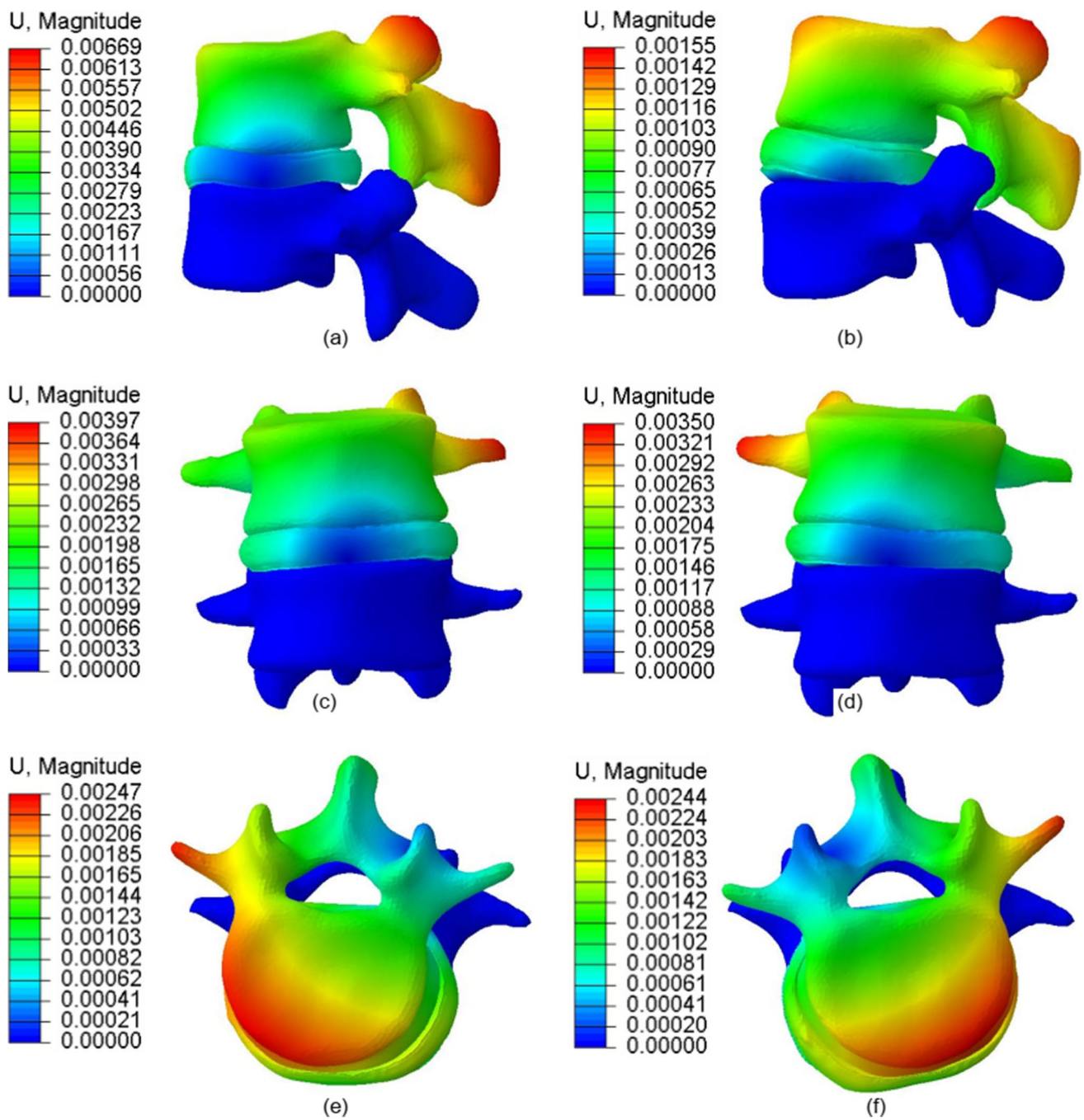


Fig. 6 The displacement contour plot of the FSU in all motions (a) flexion, (b) extension, (c) right lateral bending, (d) left lateral bending, (e) right torsion, (f) left torsion

Campbell et al. [26] compared posterolateral fusion and interbody fusion (PLIF/TLIF) for degenerative spondylolisthesis and reported no statistically significant difference in functional and operative outcomes following fusion alone versus with interbody. However, the results of biomechanical studies are different. Lu et al. [27], in a FE analysis study, compared PLF and other interbody fusion constructs (TLIF/OLF/XLIF) and found that RoM was comparable

among different constructs (0.28–0.47 degrees) in bending and rotation. However, in extension and flexion, the RoM with PLF (1.01–1.05 degrees) was greater than LIF (0.48–0.72 degrees). The presented FEA study showed a greater reduction in extension and torsion RoM (6% and 12% difference respectively) on comparison of interbody procedures (TL+BPS/PL+BPS) with instrumented laminectomy (LM+BPS), while no considerable difference in

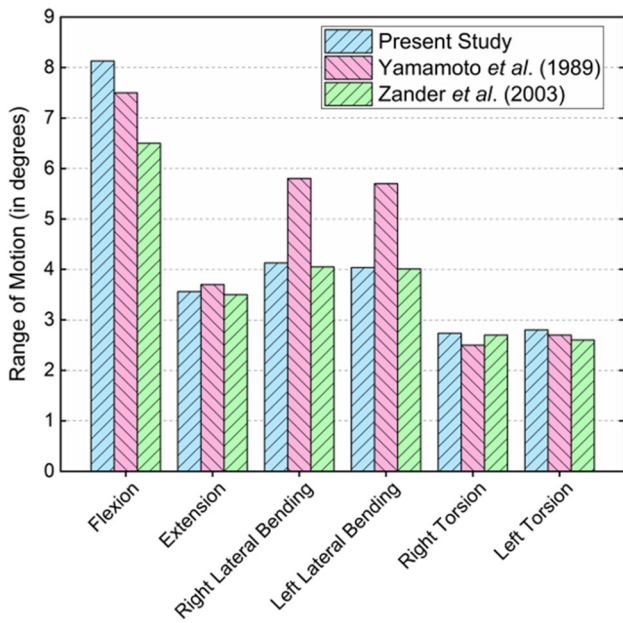


Fig. 7 The validation of the RoM of FE model in all motions with literature

reduction in RoM (<5% difference) in flexion and bending. Thus, interbody procedures could impart additional stability in extension and axial torsion over laminectomy.

Interbody fusion procedures are gaining importance as the insertion of interbody devices increases surface area for fusion, improve sagittal alignment and restore disc and foraminal height, providing indirect decompression and aiding in spondylolisthesis reduction [28]. PLIF requires resection of midline structures and retraction of the dural sheath to access disc space. At the same time, TLIF has the advantage of preserving ligamentous structures, which are instrumental in restoring biomechanical stability of the segment and decreasing the chances of neural injury due to less dural retraction [29]. Several clinical studies have proved decreased complication rates, blood loss, and operative

time with TLIF compared to PLIF, even though clinical outcomes are almost similar in both cases [6, 7]. Several authors have tried to evaluate the superiority of one procedure over another biomechanically. Ames et al. [11], through a cadaveric study (human lumbar spine L1-L5), showed that the rigidity of single level PLIF constructs increased after instrumentation with pedicle screws compared to TLIF, with a significant decrease in flexion–extension (0–0.05). However, no significant difference in stability was noted between TLIF and PLIF across two levels after pedicle screws were added. Sim et al. [9], by a cadaveric study, observed that PLIF provided higher immediate stability than TLIF, especially in lateral bending. Nevertheless, no difference was observed in other biomechanical properties regarding RoM, Intradiscal pressure, and laminar strain at the adjacent segments. However, FEA studies noticed slightly different results than cadaveric studies. Xu et al. [10] conducted an FEA study and reported that the differences in the RoM between PLIF and TLIF were insignificant; it is less than 1 degree for all loading cases. The current study reciprocated the results by Xu et al. [10]. In the present study, both PLIF and TLIF with pedicle screw instrumentation had a drastic decrease in RoM compared to the intact FE model (about 90% reduction), but there was less than a 5% difference in RoM reduction between PLIF and TLIF group with pedicle screw instrumentation showing no biomechanical superiority of one over another. Thus, single-level TLIF and PLIF achieved an almost similar reduction in RoM for all the motions.

The bilateral pedicle screw fixation after interbody fusion is regarded as a standard surgical method for degenerative lumbar diseases. However, the significant blood loss, operative time, implant cost, and device-related osteoporosis with bilateral instrumentation led to the increasing use of unilateral instrumentation. Most level 1 evidence studies in the literature [12, 13, 30] showed no difference between either unilateral or bilateral pedicle screw fixation in TLIF in terms of clinical outcomes and fusion rates. However, meta-analyses

Table 3 Comparison of the Range of Motion in all the motions of the modified FE models (% reduction is calculated via Eq. 1 and reported in the parentheses)

Motion	Intact	LM + BPS	PL + UPS	TL + UPS	PL + BPS	TL + BPS
Flexion	6.89	0.66 (90.4)	1.08 (84.3)	1.09 (84.2)	0.42 (93.7)	0.44 (93.6)
Extension	3.59	0.65 (81.9)	1.082 (69.8)	1.09 (69.6)	0.42 (88.3)	0.44 (87.7)
Right lateral bending	4.11	0.49 (88.0)	1.43 (65.2)	1.54 (62.6)	0.44 (89.2)	0.45 (89.1)
Left lateral bending	4.07	0.49 (87.9)	1.41 (65.3)	1.53 (62.4)	0.44 (89.1)	0.45 (88.9)
Right Torsion	2.67	0.59 (77.9)	0.31 (88.4)	0.36 (86.5)	0.27 (89.8)	0.26 (90.3)
Left Torsion	2.74	0.59 (78.4)	0.29 (89.4)	0.36 (86.9)	0.27 (90.1)	0.26 (90.5)

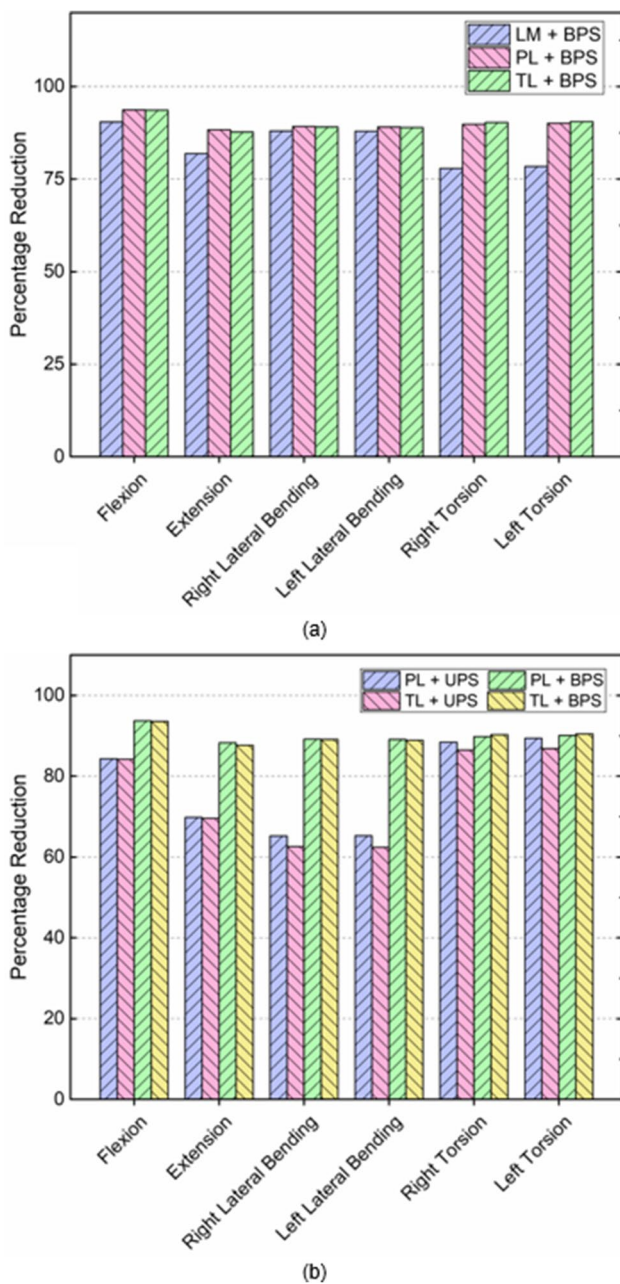


Fig. 8 The % reduction of RoM of FE models after decompression surgeries (a) comparison between bilateral instrumented Laminectomy (LM+BPS), bilateral instrumented Posterior Lumbar Interbody fusion (PL+BPS) and bilateral instrumented Transforaminal Lumbar Interbody fusion (TL+BPS) (b) comparison between unilateral Instrumented Posterior Lumbar Interbody fusion (PL+UPS), unilateral instrumented Transforaminal Lumbar Interbody fusion (TL+UPS), PL+BPS and TL+BPS

done by Zhao Y et al. [13], Lu P et al. [30], and Ren C et al. [31] have shown an increased risk of cage migration with unilateral fixation with TLIF. Ren C et al. [31] have reported lower fusion rates with unilateral fixation with TLIF. It was evident that blood loss, operative time, instrumentation load,

and cost would be low in unilateral instrumentation. Even though many clinical studies showed no difference in the clinical outcome parameters, there is no long-term follow-up of clinical parameters like pain around surgical fusion, implant failure rate, and re-surgery rate.

FEA’s numerical biomechanical analysis showed higher stress in unilaterally instrumented constructs than bilateral instrumented ones. The current study showed a drastic difference in the reduction of RoM between unilateral and bilateral instrumentation with TLIF with a maximum difference in left bending (26.5%). Various FEA studies done in the past [14, 15, 32, 33] showed that TLIF augmentation with bilateral posterior fixation increases fusion construct stability by decreasing RoM and decreases posterior instrumentation stress compared to unilateral instrumentation. Ambati et al. [14] found a maximum difference in stability in left lateral bending, which is consistent with the presented results. Chen et al. [15] reported TLIF oblique model with UPS increased motion at surgical level mostly in right lateral bending (59% higher) and right axial rotation (32% higher). Yang et al. [33] also showed a maximum difference in lateral flexion between unilateral and bilateral screw fixation with TLIF. Slucky et al. [33], in a cadaveric study, reported significantly increased segmental range of motion, less stiffness, and off-axis movement with unilateral fixation with TLIF. The maximum difference in RoM in lateral bending between the two constructs was also reported by Slucky et al. [34]. Therefore, it can be concluded that the bilateral screw fixation provides biomechanically superior to unilateral fixation in both PLIF and TLIF groups in all motions except in torsion.

7.1 Limitations

FE model in the current study was generated from the CT of a healthy subject, so the effects of other pathological conditions on the spine's stability after these procedures need to be further investigated. Also, the effects of muscle forces and other dynamic stabilizers were not considered. Another limitation of the current study was that intradiscal pressure, adjacent segment changes, and vonMises stress were not analyzed for biomechanical stability. In the current FE model, no axial/body load is considered and the validation with literature is carried out with only a moment load. The annulus fibrosus can be modeled as a fiber-reinforced biological composite, but for the current study, it is modeled as linear elastic material because the main aim of this study was to model the instrumentation and decompression surgeries. The FE model is validated with in-vitro experimental studies that use the entire lumbar spine. This may not be an ideal comparison because only a single FSU (L3-L4) is modeled in this study. For this, the authors are working on a study that validates and uses FE model of the entire lumbar spine.

8 Conclusion

Based on the presented FEA study results, Laminectomy, TLIF, and PLIF with pedicle screw instrumentation showed a considerable decrease in RoM compared to the Intact FE model. In comparison with LM + BPS, interbody procedures (PL + BPS and TL + BPS) showed a considerable reduction in RoM in extension and torsion (6% and 12% difference respectively), while no considerable difference was noted in the reduction in RoM (< 5% difference) in flexion and bending. Single level TLIF and PLIF achieved an almost similar reduction in RoM with in < 5% difference. Bilateral screw fixation proved biomechanically superior to unilateral fixation in both PLIF and TLIF groups in all motions except in torsion. Hence, TLIF with bilateral pedicle screw fixation can offer a biomechanical advantage over traditional instrumented laminectomy in decreasing RoM and stability in extension and torsion. Also, it can be favored over other interbody procedures like PLIF due to fewer complications like dural tear and no biomechanical difference.

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Methodology: Shivam Saini, Manish Kumar, Subrato Sarkar;

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Declarations

Presentation The authors declare that any portion of the contents of the paper has not been presented previously.

Ethics approval We conducted our study after obtaining institutional ethical clearance from the ethical committee of AIIMS Rishikesh, India.

Conflict of interest The authors declare no competing interests.

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