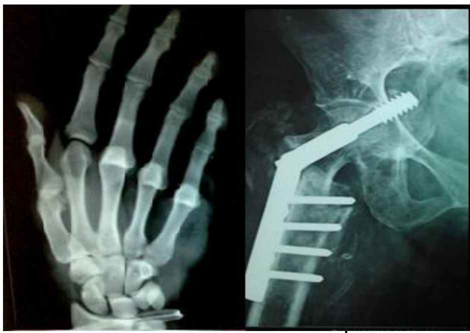

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Biomechanical comparison of lumbar spine stability after laminectomy versus bilateral laminotomy: An experimental study in porcine model

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Abstract
Background: Rationality of the lumbar spine is inferable to many structures in the practical spinal unit**.** The alliance of lumbar spine unreliability between laminectomy and laminotomy had been clinically studied, but the corresponding *in vitro* biomechanical studies are very limited. We explored the hypothesis that the uprightness of the posterior complication plays a vital role on the post-operative spinal rationality in decompressive surgery.
Methods: Twenty porcine lumbar spine samples had been studied. Each sample was tested as a whole & after two decompression mechanism. All posterior elements were upheld in Group I (Intact). In Group II (Bilateral laminotomy), the subservient margin of the L4 lamina and predominent margin of the L5 lamina were detached, however the L4 and L5 supraspinous ligament was upheld. Fenestrations design was made on either side. In Group III (Laminectomy) lamina and the spinous activities of lower L4 & upper L5 were detached. Ligamentum flavum & supraspinous ligaments of L4 and L5 were detached. Hydraulic machine for testing was used for the generation of an increasing moment up-to 9000 N-mm in bending of limb and extension. Intervertebral movement at the decompressive level L4 and L5 was evaluated by Extensometer.
Results: In extension motion, intervertebral movement between the specimen in complete form and at two dissimilar decompression levels did not remarkably differ ($P>0.05$). However, In flexion motion, intervertebral movement of laminectomy specimens at the decompression level L4 and L5 was significantly more than in intact or the bilateral laminotomy specimens ($P=0.392$ and $P = 0.0001$, $P = 0.00001$). No significance difference was established between intact and the bilateral laminotomy groups ($P>0.05$).
Conclusion: In this experimental study we concluded that Bilateral laminotomy is a more stable surgical procedure as compared to laminectomy in the decompressive surgery of lumbar spine.

Keywords: Biomechanical comparison, lumbar spine stability, laminectomy versus bilateral laminotomy

Introduction
Rationality of lumbar spine is obtainable to various structures in the practical spinal unit. These structures are either more or less bony, discoligamentous or muscular in form [1].
Loss of stability can be less important to physiological ageing or disorder that alters the uprightness of stabilizing structures. The Iatrogenic instability may also be found after the surgery because of damage or detachment of these structures. Depending upon which structures were disturbed, the spine may acquire hypermobility and reduce stability in various planes of movement like sagittal, coronal movement, and axial. It has been recognized that surgical decompression of the spinal stenosis is stable between adequate detachment of bone and pappy tissue for a constructive decompression of the neural structures, and retention of sufficient bone and pappy tissue structures to maintain the mechanical rationality of the spine [2].
Traditionally surgical treatment is carried out by the decompressive laminectomy with controlled facetectomy. Few authors recommend a less invasive method using a laminotomy or fenestration technique. The logic for this was, the decreased in patient morbidity and very fast recovery with limited operation, limiting the surgery to the pathologic area, decreased post-operative radiographic listhesis and potentially restrict the requirement for the fusion.

But clinical studies have proven a tendency to listhesis following laminectomy [3].

Bilateral laminotomy conserves the midline ligamentous structures that are thought to play the vital role in maintaining the firmness of the motion segment, and decreasing post-operative listhesis. Several biomechanical studies have scrutinized the role of posterior midline ligaments to the firmness of the spine. These results indicate that interspinous and the supraspinous ligaments confer in restricting the spinal motion, mainly in flexion [4].

Biomechanical testing for the stability firmness of the spine can be done by a specially designed extensometer. While testing, intervertebral movement at decompression levels can be recorded continuously [5].

The purpose of the study is to compare the spinal stability after laminectomy and the bilateral laminotomy in porcine model in order to investigate the speculations that the uprightness of the posterior complex plays the vital role on the post-operative spinal stability in decompressive surgery.

Materials and Methods

This experimental study was done in the department of Orthopaedics for the duration of 12 months, on porcine models after obtaining the approval of Institutional Ethical Committee.

Twenty adult porcine lumbosacral spines (L1–S1) were included in study.

Study Design

It was an experimental consisting of 20 specimens.

All Adult porcine models were included except the one with obvious underlying bony deformity.

Study Protocol

Paraspinal muscles of every specimen were wholly excised, and all the ligamentous components, which include supraspinous ligaments, were precisely preserved. Each of the twenty porcine lumbar spines was tested in intact form, after the bilateral laminotomy and after laminectomy surgery.

All posterior elements were preserved in the intact group. In the bilateral laminotomy group, the fenestration was done on both the sides of lamina. The inferior margin of the L4 lamina and superior margin of the L5 lamina were detached, and the L4–L5 ligamentum flavum was impaired. L4–L5 supraspinous ligament were preserved in all the specimens. Eventually, in laminectomy group, the lamina and spinous processes of the lower L4 and the upper L5 was removed. The ligamentum flavum and the supraspinous ligament of L4–L5 were also detached. Preservation of the bilateral L4–L5 facet joints was confirmed in all the specimens.

Biomechanical Test

The specimens were prepared for biomechanical testing through specially designed attachment used to increase up to 9000NM moment generated by the axial movement was applied to all the specimens to gain the flexion and extension motions. During testing, intervertebral movement at the decompression levels L4 and L5 was recorded continuously with the help of an extensometer.

During testing, the intervertebral displacement information was simultaneously recorded.

Six intervertebral displacements computed of L4–L5 lumbar segment were done in each porcine model.

1. Intact under flexion;
2. Intact under extension;
3. Bilateral laminotomy in flexion;
4. Bilateral laminotomy in extension;
5. Laminectomy under flexion;
6. Laminectomy under extension.

All measurements were performed using unique testing procedures. The stability of the lumbar spine in intact form, following bilateral laminotomy and the laminectomy was evaluated by comparing the data by statistical analysis.

Data Management & Statistical Analysis

Interpretation and analysis was subjected to standard statistical analysis using the latest SPSS version 22.

Data was represented in the form of mean ± standard deviations.

Paired t-test was used to compare the mean value between the Groups i.e. intact, laminectomy and the bilateral laminotomy for the above mentioned parameter both under flexion and extension separately. Result with value $P<0.05$ was considered to be significant

Fig 1

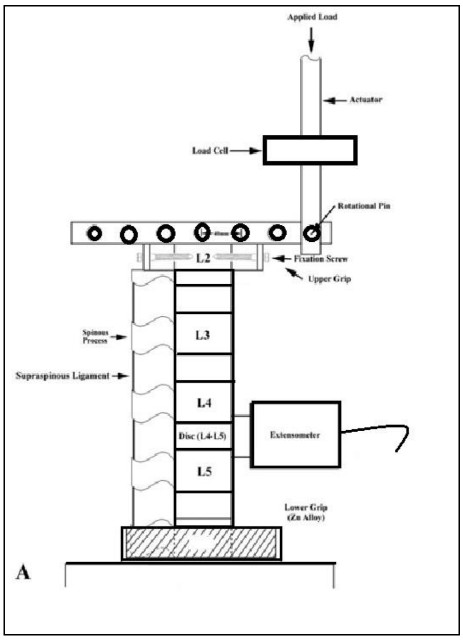

Fig 2

Results

In this experimental study all samples were exposed to mechanical testing in 3 Groups

Group I: Intact porcine model

Group II: Porcine model after Bilateral Laminotomy

Group III: Porcine model after Laminectomy

Refer to table 1 for Average motion for all groups [STD- standard deviation, SEM- standard error of mean]

On referring to table 2, for comparison of intervertebral displacement of L4–L5 segment in flexion and extension of in intact and the bilateral laminotomy groups.

So it was seen that the contrast between the flexion and the extension of Group I and Group II was statistically not significant (P>0.05) at 5% level of significance. It indicates that bilateral laminotomy does not disturb the spinal stability under flexion and extension withr defined mechanical load.

On referring to table 3, intervertebral displacement of L4–L5 segment under flexion and extension in intact and laminectomy groups.

So it was seen that the difference between the flexion and extension of Group I and Group III was statistically significant (P<0.05) at 5% level of significance. It indicates that laminectomy disturbs the spinal stability in flexion and extension under defined mechanical load.

On referring to table 4 intervertebral displacements of L4–L5 segment in flexion and extension in bilateral laminotomy and the laminectomy groups

So it was seen that the contrast between flexion and the extension of Group II and Group III was statistically significant (P<0.05) at 5% level of significance. By comparing the bilateral laminotomy and the laminectomy group it was found that spine became significantly unstable after laminectomy under flexion and extension in comparison to bilateral laminotomy.

It was observed that the average changes in intervertebral disc space mean value -0.491335, -0.513630, -0.674120 in flexion of intact, bilateral laminotomy, and laminectomy.

However in extension the mean value of 0.354620, 0.357260, 0.553830 were found respectively.

It was observed that intervertebral displacement in flexion with bilateral laminotomy was 4.5% and in laminectomy was 37% in relation to intact spine. While in extension the displacement was 0.84% and 56% with bilateral laminotomy and the laminectomy respectively as compared to intact spine.

Discussion

Laminectomy is one of the commonest effective decompressive procedures for lumbar stenosis with success rate ranging from 70% to 90% [6]. Although effective in treating neurogenic claudication, the incidence of post-operative spondylolisthesis has been reported to range from 8% to 31% due to loss of uprightness of posterior osteoligamentous complex [7]. Thus, in recent years bilateral laminotomy has gained popularity as it is equally effective for decompression with intact integrity of posterior complex and preserving the spinal stability.

Till date, very few biomechanical comparison studies between laminectomy and the bilateral laminotomy for lumbar spine instability have been reported. Thus, to evaluate the role of integrity of posterior complex in postoperative spinal stability we conducted an experimental study.

Hans-Joachim Wilke *et al* presented the biomechanical properties of each single motion segment of porcine spine and compared them with human spine. They found that ROM of the porcine spine for various loading directions is quantitatively similar to the data of human specimens. Thus, the use of porcine spine may be an alternative to the human specimens *in vitro* research [8].

During mechanical testing in our study it was found that under flexion and extension, an average intervertebral displacement of L4-L5 segment in intact and after bilateral laminotomy was statistically not significant (P>0.392, P>0.921). However, the average intervertebral displacement showed statically significant difference between intact and laminectomy group (P<0.0001, P<0.00001) and between bilateral laminotomy and the laminectomy groups (P<0.00001, P<0.0001), which suggests bilateral laminotomy is a more stable surgical procedure.

Tai *et al* in their experimental study in eight porcine models, comparing lumbar spine instability in between laminectomy and the bilateral laminotomy for the spinal stenosis found that under flexion, intervertebral displacement of the laminectomy specimens at the decompression level L4–L5 was statistically higher than in intact or the bilateral laminotomy specimens (P = 0.0000963 and P = 0.000418 respectively). No difference was seen between intact and the bilateral laminotomy groups. (P>0.05). The author concluded that the integrity of the posterior complex plays a vital role on the post-operative spinal stability in the decompressive surgery. Thus, the findings of our study are corresponding with the findings of this study [9].

Postacchini *et al* compared the multiple Laminotomy and the total laminectomy in 67 post operative patients with central lumbar stenosis. Post multiple laminotomy, not a single patient had postoperative vertebral instability, whereas after laminectomy 10% patients developed postoperative vertebral instability. Thus, the author proposed that multiple laminotomy with its better preservation of vertebral stability is the selective treatment for developmental stenosis and with mild to moderate degenerative stenosis or degenerative spondylolisthesis [10].

Katz *et al* reported that out of eighty-eight successive patients those who had a laminectomy for the degenerative lumbar stenosis, 15 patients (17 %) developed spinal instability [11].

Lu *et al* found the destabilization from the multilevel bilateral laminotomy. Overall, the motions in antero-posterior translation showed no statistically remarkable difference between the intact spine and the spine with the multilevel laminotomy. In this study also, no significant difference in the intervertebral displacement between intact and bilateral laminotomy group was found. Thus,our findings are in concordance with this study [12].

Although this was an experimental study done on the porcine models, results show that the laminectomy produces mechanical instability in comparison to bilateral laminotomy. These results are similar to the other studies available for comparison in the literature.

Despite these findings, ultimately, the decision to do the laminectomy or the laminotomy has to be a clinical judgment based on the combination of surgeon, patient and the disease factors.

Table 1: Average motion for all groups

Groups	Mean	STD	SEM
Intact (Flexion)	-0.491335	0.1459557	0.0326367
Intact (Extension)	0.354620	0.1194388	0.0267073
Bilateral laminotomy (Flexion)	-0.513630	0.1688063	0.0377462
Bilateral laminotomy (Extension)	0.357260	0.1364456	0.0305102
Laminectomy (Flexion)	-0.674120	0.2314639	0.0517569
Laminectomy (Extension)	0.553830	0.1694258	0.0378848

Table 2: Comparison of intervertebral displacement of L4–L5 segment under flexion and extension of in intact and bilateral laminotomy groups.

	Group I (Intact) mean value	Group II (Bilateral Laminotomy) mean value	P value
Flexion	-0.491	-0.5136	0.392 (NS)
Extension	0.354	0.357	0.912 (NS)

Table 3: Intervertebral displacement of L4–L5 segment under flexion and extension in intact and laminectomy groups.

	Group I (Intact) mean value	Group III (Laminectomy) mean value	P value
Flexion	-0.491	-0.674	0.0001 (S)
Extension	0.354	0.553	0.00001 (S)

Table 4: Intervertebral displacement of L4–L5 segment under flexion and extension in bilateral laminotomy and laminectomy groups.

	Group II (Bilateral Laminotomy) mean	Group III (Laminectomy) mean value	P value
Flexion	-0.513	-0.674	0.00001 (S)
Extension	0.357	0.553	0.0001 (S)

Conclusion

After evaluating the results of this experimental study we conclude.

The average intervertebral displacement of L4-L5 segment under flexion and extension with the defined mechanical load between intact and the bilateral laminotomy group was statistically not significant ($P>0.05$). This suggests that bilateral laminotomy does not disturb the spinal stability

The average intervertebral displacement of L4-L5 segment under flexion and extension in defined mechanical load between intact and laminectomy group was statistically significant ($P<0.05$). This suggests that laminectomy causes spinal segmental instability.

While comparing laminectomy to bilateral laminotomy the average intervertebral displacement of L4-L5 segment was found to be significant ($p<0.05$). This suggests the integrity of the posterior osteoligamentous complex helps to maintain the segmental stability of the decompressive spine.

Thus, bilateral laminotomy is a more stable surgical procedure in contrast to laminectomy in the decompressive surgery of lumbar spine.

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