Biomechanical comparison of laminotomy versus laminectomy- A cadaveric study

Sidharth Madaan¹, Vijendra D. Chauhan¹, Aksh Dubey¹, IndraVir Singh¹
¹Department of Orthopaedics, ²Department of Anatomy, Himalayan Institute of Medical Sciences, Swami Rama Himalayan University, Dehradun, Uttarakhand.

Background: Stability of the lumbar spine is attributable to several structures in the functional spinal unit. The association of lumbar spine instability between laminotomy and laminectomy has been clinically studied, but the corresponding in-vitro biomechanical studies are very limited. Using a cadaveric simulation model we compared lumbar spine stability after unilateral laminotomy, bilateral laminotomy and laminectomy in fresh frozen human cadaver models on mechanical loading.

Materials & Methods: Ten fresh frozen human cadaver lumbar spine specimens were studied. Each specimen was tested intact (Group I), after unilateral laminotomy (Group II), bilateral laminotomy (Group III) and laminectomy (Group IV). Universal testing machine was used to generate physiological loading in flexion, extension and lateral bending. Intervertebral displacement was measured by extensometer.

Results: Under flexion motion, intervertebral displacement of laminectomy (Group IV) specimens at decompression level L3–L4 was statistically greater as compared to intact, unilateral or bilateral laminotomy specimens (p<0.05). No significant difference was found among any of the other movements (p> 0.05).

Conclusions: Unilateral laminotomy and bilateral laminotomy are more stable surgical procedures. Laminectomy causes spinal segmental instability in flexion. Integrity of posterior osteoligamentous complex helps to provide segmental stability of the decompressive spinal unit.

Introduction

Stability of the lumbar spine is attributable to several structures in the functional spinal unit. These structures are bony, ligamentous or muscular in nature. Injury to any of these structures may result in spinal instability.¹ Physiological ageing, diseases altering the integrity of the stabilizing structures, iatrogenic injuries and surgical injuries can result in secondary loss of stability. Instability can be in various planes and it would depend on the spinal structures disturbed. One has to be very careful during surgical decompression of spinal stenosis, as surgery should be a balance between adequate removal of bone and soft tissue for an effective decompression of neural structures and sufficient retention of bone and soft tissue structures to maintain mechanical stability of the spine.² Punjabi MM defined clinical instability as “significant decrease in the capacity of the stabilizing system of the spine to maintain the intervertebral neutral zones within the physiological limits so that there is no neurological dysfunction, no major deformity and no incapacitating pain”.³

Animal models are useful in studying some specific aspects of disc biology, but inappropriate use of animal models serve to spread incorrect information about the processes involved in disc degeneration and about the possibilities of repair. Work on animal tissue is useful to help in the development of techniques and provide baseline data; but work should ideally be done on human tissue. If we want to improve understanding of pathology and treatment of human inter-vertebral disc lesions, human tissues should be accessed from cadaveric organ donor source.⁴

Several biomechanical studies have examined the contribution of midline ligamentous structures, which are thought to play a major role in maintaining the stability of spine. These studies suggest that
interspinous and supraspinous ligaments contribute to restricting the spinal motion in flexion, anterior longitudinal ligament in extension and contralateral transverse ligament in lateral bending.

Biomechanical testing for stability of the spine can be done by a specially designed extensometer. During testing, intervertebral displacement at decompression levels can be recorded continuously.

This study was undertaken to compare the spinal stability after unilateral laminotomy, bilateral laminotomy and laminectomy in human cadaver model in order to investigate whether the integrity of the posterior complex plays an important role in the postoperative spinal stability in decompressive surgery.

**Materials and Methods:**

Ten fresh frozen human cadavers were obtained from cadaveric lab and were thawed before use. Lumbar spines were radiographed in the anteroposterior and lateral views to rule out any previous trauma or significant pathology. In each cadaver, the lumbar spine (L1-L5) was dissected to remove the soft tissues (musculature) while preserving the osteoligamentous structures (vertebrae, ligaments, and intervertebral discs). The lumbar spine from L1–L5 was taken out enblock with the help of saw. The specimens were double-bagged and stored at -20°C when not being tested.

To prepare each specimen for testing, the specimen was thawed again. Each specimen was placed on fixture and fixed with four metal screws of approximately 6 cm length into the terminal ends of lumbar vertebrae (L1 and L5). The specimen was mounted on universal testing machine (Kalpak SR.NO.130502) (Figure 1) to apply bending movement and extensometer (Figure 2) was fixed to spine for measuring intervertebral displacement at L3-L4 level.

**FIGURE 1: Spine model mounted on universal testing machine**

Four groups were created. In Group 1, no surgery was performed i.e. all ligaments and bony structures were maintained intact. Bending movements were applied in flexion (8 Nm), extension (6 Nm), left lateral bending (6 Nm) and right lateral bending (5 Nm), and intervertebral displacement at L3-L4 level was measured.

This specimen was then subjected to unilateral lumbar laminotomy at L3-L4 level (Group II) which entailed removal of ligamentum flavum and partial facetectomy of one side to visualize the medial aspect of the pedicle to ensure adequate lateral recess decompression. The spinous process, interspinous ligaments and supraspinous ligaments were preserved. The previously mentioned movements under the prescribed loads were measured again.

The same specimen was then subjected to lumbar laminotomy at L3-L4 level on the other side also i.e. bilateral laminotomy (Group III). The previously mentioned movements under the prescribed loads were measured again.

Finally, the bilateral laminotomy were converted into total laminectomy at L3-L4 level (Group IV) which entailed full removal of the lamina, supraspinous ligaments, interspinous ligaments and spinous processes. The previously mentioned movements under the prescribed loads were recorded.

All measurements were carried out using identical testing procedures. The stability of the intact lumbar spine (Group I), lumbar spine with unilateral laminotomy (Group II), lumbar spine with bilateral laminotomy (Group III) and lumbar spine with laminectomy (Group IV) were evaluated.

**Data Management & Statistical Analysis:**

The data was subjected to standard statistical analysis using the SPSS version 22.0. Wilcoxon signed-rank test was used to evaluate the difference across the four groups in flexion, extension, left lateral bending and right lateral bending separately. Results with value p<0.05 were considered to be significant.
Results:
In flexion, the mean value of inter-vertebral displacements in groups were: Group I: -0.85961 mm, Group II: -0.86719 mm, Group III: -0.88791 mm and Group IV: -1.16539 mm. The percentage increase of intervertebral displacements were 0.88%, 3.29% and 35.57% in Group II, Group III and Group IV respectively in relation to Group I.

In extension, the mean value of intervertebral displacements in various groups were: Group I: 0.76483 mm, Group II: 0.77083 mm, Group III: 0.77487 mm and Group IV: 0.79313 mm. The percentage increase of intervertebral displacements were 0.78%, 1.31% and 3.7% in Group II, Group III and Group IV respectively in relation to Group I.

In left lateral bending, the mean value of intervertebral displacements in groups were: Group I: -0.50447 mm, Group II: -0.50695 mm, Group III: -0.51041 mm and Group IV: -0.51142 mm. The percentage increase of intervertebral displacements were 0.49%, 1.18% and 1.38% in Group II, Group III and Group IV respectively in relation to Group I.

In right lateral bending, the mean value of intervertebral displacements in various groups were: Group I: 0.49921 mm, Group II: 0.50171 mm, Group III: 0.50494 mm and Group IV: 0.50821 mm. The percentage increase of intervertebral displacements were 0.5%, 1.15% and 1.8% in Group II, Group III and Group IV respectively in relation to Group I.

The mean difference between flexion, extension, left lateral bending and right lateral bending of Group I and Group II are as shown in Table 1. No statistical significant difference was found between Group I and Group II.

The mean difference between flexion, extension, left lateral bending and right lateral bending of Group I and Group III are as shown in Table 2. No statistical significant difference was found between Group I and Group III.

The mean difference between flexion, extension, left lateral bending and right lateral bending of Group I and Group IV are as shown in Table 3. A statistical significant difference in intervertebral displacement was seen between flexion of group I and IV (p = 0.005). However, no statistical significant difference was seen between extension, left lateral bending and right lateral bending of Group I and Group IV respectively.

Discussion:
Decompression of spine is needed in patients with neurological claudication and lumbar stenosis. For adequate decompression many surgeons used to do christmas tree laminectomy which entailed bilateral facetectomies and foraminotomies. This technique was successful in adequately decompressing the spine but
incidence of post-operative spondylolisthesis was very high and therefore neurological symptoms recurred. Fusion with instrumentation was a routine procedure done after Christmas tree laminectomy to stabilize the spine. In view of complications, facet sparing laminectomy was introduced which provided the same amount of decompression as Christmas tree laminectomy, but reduced the post-operative listhesis. Facet sparing laminectomy has been a procedure of choice for many years with a success rate of about 80%. Although the procedure is very effective, still the incidence of post-operative spondylolisthesis has been reported up to 31% in patients without preoperative listhesis and in 73% patients with preoperative listhesis, progression of listhesis being observed in either case. In order to reduce the risk of post-operative spondylolisthesis, less invasive techniques like laminotomy have gained popularity as posterior ligamentous complex is spared and acts as a stabilizer to lumbar spine.

There are biomechanical studies comparing the stability of spine after laminotomy and laminectomy in animal models, but animal models only provide the baseline data. The best option would be a human model.

In our study, spine model was mounted on universal testing machine for loading and intervertebral displacements were measured by extensometer. Many studies had already been done where extensometer had been used to measure intervertebral displacements. During mechanical testing, intervertebral displacement increased as applied load increased. The maximum displacement was present at peak loads of 8 Nm in flexion and 6 Nm in extension. When loading reached the pre-defined values, further loading was stopped and readings were noted. Under flexion motion, intervertebral displacement kept on increasing as loading was increased in all four groups, but under extension motion, facet joints locked on loading and prevented posterior vertebral displacement, which caused the movement to increase rapidly to end point of loading without much displacement. We found in our study that intervertebral displacement in flexion, extension and lateral bending among intact, unilateral laminotomy and bilateral laminotomy groups were statistically not significant (p>0.05). Intervertebral displacement in extension and lateral bending between intact and laminectomy group were also statistically not significant (p>0.05), however intervertebral displacement in flexion between intact and laminectomy group was found to be statistically significant (p<0.05). Similar observations were made by Tai CL et al. in their experimental study in eight porcine models, comparing lumbar spine instability between bilateral laminotomy and laminectomy. They found that under extension, intervertebral displacements after laminotomy and laminectomy was statistically not significant. Under flexion intervertebral displacements after laminotomy was not significant, however after laminectomy flexion was statistically significant. The author concluded that the integrity of the posterior complex plays an important role on the postoperative spinal stability in decompressive surgery, however, Rao RD et al. in their mechanical study on nine fresh calf spines compared bilateral laminotomy and laminectomy to quantify spinal segmental instability. They found that after laminotomy and laminectomy there was significant increase in segmental motion under flexion and extension. Under lateral bending no significant increase was observed after both the procedures.

Lee MJ et al. compared bilateral laminotomy and facet sparing laminectomy in six fresh frozen cadaveric lumbar spines and found that in flexion and extension bilateral laminotomies resulted in an average increase range of motion by 14.3%, whereas a full laminectomy resulted in an increase of 32.0% (p<0.05). There was an approximate two fold increase in motion with laminectomy compared with bilateral laminotomies. In our study, we observed the intervertebral displacement in flexion with bilateral laminotomy was 3.3% and in laminectomy was 35.57% in relation to intact spine. While in extension the displacement was 1.3% and 3.7% with bilateral laminotomy and laminectomy respectively as compared to intact spine. Thus, our study also supports that laminotomy induces significantly less iatrogenic hypermobility than laminectomy in the lumbar spine.

Postacchini F et al. compared multiple laminotomy and total laminectomy in 67 post operative patients with central lumbar stenosis. In post multiple laminotomy not a single patient had postoperative vertebral instability, whereas after laminectomy 10% patients developed postoperative vertebral instability. Thus, the authors propose that multiple laminotomy with its better preservation of vertebral stability is the treatment of choice for developmental stenosis and with mild to moderate degenerative stenosis or degenerative spondylolisthesis.

Ho YH et al. compared unilateral laminotomy, bilateral laminotomy and laminectomy. Ten porcine lumbar spines were biomechanically tested under
flexion and extension. They also observed that laminotomy entails higher spinal stability than laminectomy, with no significant differences between bilateral and unilateral laminotomies. Their results were comparable to our study.

Hopp E et al. did a study on 344 patients who had total facetectomy and pars excision for lumbar stenosis. They found 16 patients had post decompression slips. Thirteen slips were forward, two retro and one rotatory at the decompression level. They proposed that surgical removal of posterior constraints accelerate degeneration in a disc. Without posterior support and constraint, instability may occur and allow increased, non-physiologic motion which can lead to spondylolisthesis, trauma to neural elements, facet fracture and disc disruption. They also proposed that facetectomy and pars excision lead to instability so they recommended that during surgical decompression for spinal stenosis, the posterior elements must be spared as much as possible to avoid instability after surgery and fusion should be combined with it.

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

Limitations
This was an experimental study on fresh frozen human cadavers and best possible efforts had been made to simulate the clinical conditions. There were certain limitations of this study

Stability of spine is dependent upon bony, ligamentous and muscular structures. Role of muscles can not be included in an experimental study like ours on fresh frozen human cadavers as they can only be tested in a clinical study.

Loading conditions considered were flexion, extension and lateral bending. Further investigation on the effects of other loading conditions such as axial rotation is also necessary in the future.

This study demonstrated greater lumbar spine stability after laminotomy as compared with laminectomy; we do not recommend that laminotomy be routinely done instead of laminectomy as this was not a clinical study. In clinical practice there are numerous other important factors that contribute to surgical decision making like severity of stenosis, preoperative segmental mobility, medical co-morbidity, facet tropism, fluid within the facets and surgeon's expertise at procedure. Further studies are required to correlate with clinical outcome.

Conclusion
Unilateral laminotomy and bilateral laminotomy do not disturb the spinal stability and are more stable surgical procedures. Laminectomy causes spinal segmental instability in flexion, whereas there is no instability in extension and lateral bending. Integrity of posterior osteoligamentous complex helps to provide segmental stability of the decompressive spinal unit.

Disclosure
The authors declare that there is no conflict of interest regarding the publication of this paper.

References


