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ORIGINAL ARTICLE / ORJİNAL MAKALE

BIOMECHANICAL COMPARISON OF INTACT VERSUS HEMILAMINECTOMY AND DISCECTOMY PERFORMED SPINE

NORMAL VE HEMİLAMİNEKTOMİ DİSEKTOMİ UYGULANMIŞ OMURGANIN BİYOMEKANİK KARŞILAŞTIRILMASI

Ahmet KARAKAŞLI[1],
İsmail Safa SATOĞLU[1],
Ceren KIZMAZOGLU[2],
Eyad SEKIK[3],
Didem Venüs YILDIZ[4],
Erdem KUMTEPE[4]

[1]Assistant Professor, Department of Orthopedics and Traumatology, Dokuz Eylül University, İzmir

[2]Neurosurgeon, Department of Neurosurgery, İzmir Katip Çelebi University, Ataturk Research and Training Hospital, İzmir.

[3]Orthopedic Surgeon, Karataş Hospital, Department of Orthopedics and Traumatology, İzmir.

[4]Dokuz Eylul University, Institute of Health Sciences, Department of Biomechanics, İzmir.

Address: Dr. Ahmet Karakaşlı, Assistant Professor, Dokuz Eylul University, Department of Orthopedics and Traumatology, İzmir.
E-mail: karakasliahmet@gmail.com
Tel: 0232 4123372
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SUMMARY:

Objective: This study aims to investigate the effects of hemilaminectomy and discectomy on the lumbar spine of the lamb by biomechanically comparing changes on motion segments between intact and hemilaminectomy discectomy performed.

Materials and Methods: Ten fresh-frozen lamb spines were used in this study. Hemilaminectomy and discectomy was performed on each spine at L4-L5 level on the left side. The biomechanical tests for both intact spine and discectomy performed spine were performed by using axial compression testing machine. The axial compression was applied to all specimens with a loading speed of 5 mm/min. 8400 N/mm moment was applied to each specimen to achieve flexion and extension motions, right and left bending through a specially designed device.

Results: In axial compression test, compression test in flexion motion and the right bending position the specimens were more stable based on displacement values. The displacement values of hemilaminectomy discectomized spines were closer to the values of intact specimens. Comparing both groups, displacement values of extension and left-bending positions were significant ($p \leq 0.05$).

Conclusion: The displacement values of hemilaminectomy and total discectomised spine specimens were similar to studies in the literature. Biomechanical instability has been achieved in a hemilaminectomy and total discectomy spine during extension and partial laminectomy side-bending movements. After a total discectomy, a reduction in annulus fibrosis tension caused laxity at the mobile spine segment. Increased mobilization caused instability at the spine mobile segment.

Keywords: Biomechanics, spine, hemilaminectomy, discectomy

Level of Evidence: Biomechanical experimental study, Level II

ÖZET:

Amaç: Bu çalışmanın amacı koyun lomber omurgasında hemilaminektomi ve diskektominin etkilerini incelemek ve hareketli segmentte meydana gelen değişikleri biyomekanik olarak sağlam omurga ile karşılaştırmaktır.

Materyal-Metod: Bu çalışmada 10 adet taze kuzu omurgası kullanılmıştır. Her omurgada L4-L5 seviyesinde sol taraftan hemilaminektomi ve disektomi uygulanmıştır. Tüm örnekler için biyomekanik testler aksiyel kompresyon test cihazı kullanılarak gerçekleştirildi. Numunelere 5mm/dk hızda aksiyel kompresyon yüklenme uygulandı. Özel yapım bir cihaz yardımıyla her numuneye 8400N/mm moment oluşacak şekilde fleksiyon, ekstensiyon, sağ ve sol eğilme yüklenmeleri uygulandı.

Bulgular: Aksiyel kompresyon testinde, deplasman hareketi açısından fleksiyon hareketi ve sağa eğilme posizyonunda numunelerin daha stabil olduğu görülmüş, hemilaminektomi ve disektomi yapılan omurların deplasman değerleri sağlam omurga sonuçlarıyla yakın değerler vermiştir. Gruplar karşılaştırıldığında; ekstansiyon ve sola eğilme pozisyonundaki deplasman değerleri açısından istatistiksel olarak anlamlı fark bulunmuştur ($P=0.034$).

Sonuç: Hemilaminektomi ve total disektomi uygulanan omurlardaki deplasman değerleri literatürdeki çalışmalarla benzer sonuçlar vermiştir. Hemilaminektomi ve total diskektomi uygulanan omurgalarda ekstansiyon ve ameliyatlı tarafa eğilme hareketlerinde instabilite saptanmıştır. Total diskektomi sonrasında, anulus fibrosis gerginliğindeki azalma ve omurga hareketlilikteki artış meydana gelmekte, bu durum hareketli omurga segmentinde instabiliteye yol açmaktadır.

Anahtar Sözcükler : Biyomekanik, omurga, hemilaminektomi, diskektomi

Kanıt Düzeyi: Biyomekanik deneysel çalışma, Düzey II

INTRODUCTION:

Low back pain has become the most common and expensive cause of chronic disability in adults under 45 years of age. Further, lumbar disc prolapsus accounts for less than 5% of all low-back problems but is the most common cause of nerve root pain[1,12]. L4-5 is the most frequently involved level, followed closely by L5-S1, then L3-4. Disc protrusion at other levels or at more than one level at any given time is rare[5,14]. Intervertebral discs play a primary and critical role in the biomechanics of the spine. They function in contributing to load bearing, impact absorption, and stress transmission between the vertebrae[10,18,19]. Biomechanics still play a major role in spinal pathology and pain[3]. After open discectomy, degenerative changes occur at the spinal motion segment. The exact occurrence mechanism of this degeneration is unknown, but some causes, such as disc height loss and increased segment motion are thought to be responsible for instability. After open discectomy, a few studies about spine instability have been reported. This research aims to investigate what degree of instability occurs within the mobile segment of fresh frozen lamb after open hemilaminectomy and discectomy.

MATERIALS AND METHOD:

The open spinal discectomy study that was performed at this stage consisted of 10 fresh frozen lamb spines. The lambs were between 6 to 12 months old. The specimens did not have any macroscopic or radiological diseases under inspection and evaluation by x-rays, respectively. The spine of each specimen was dissected from the sacrum to the T12 level. All of the specimens were frozen and thawed at room temperature the night before the surgery.

The biomechanical measurements of all specimens have been obtained preoperatively. Classical hemilaminectomy and open discectomy on left L4-L5 disc space were performed in all specimens (n=10). Following the surgery, operating measurements were obtained and the values were compared.

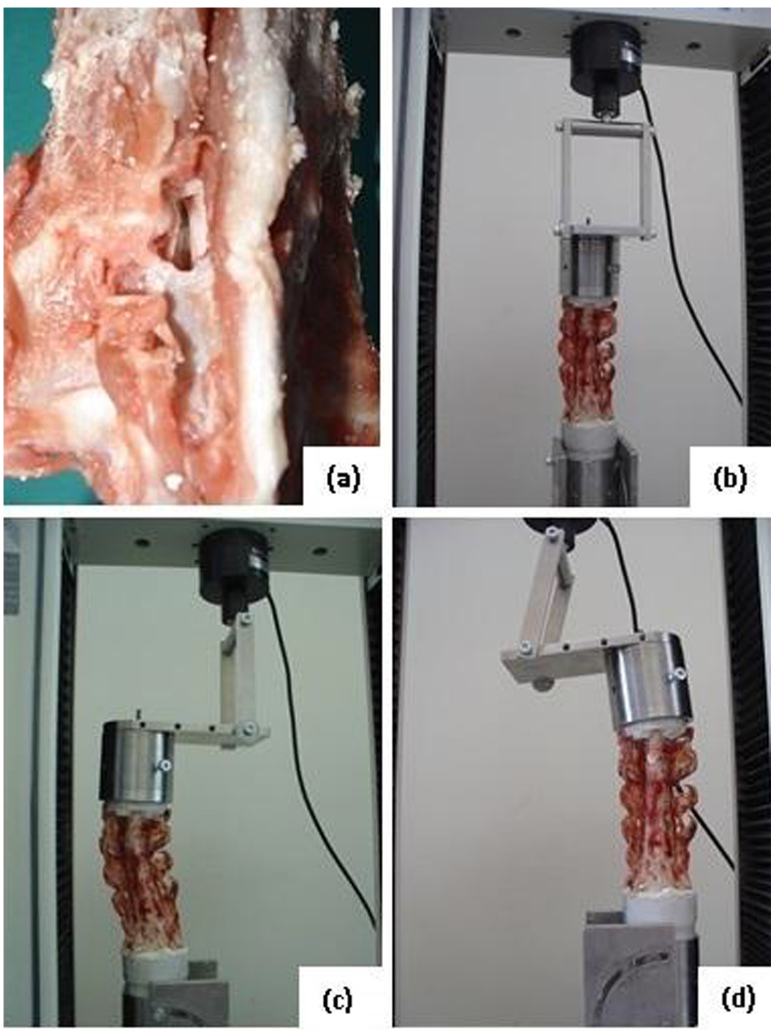

Figure-1. Various positions in biomechanical test. **(a)** Open discectomized Lumbar Lamb Spine **(b)** Axial compression test. **(c)** Right bending test. **(d)** Left bending test.

Biomechanical Tests:

The current study was performed in Dokuz Eylül University, Institute of Health Sciences, and Biomechanics Laboratory. The biomechanical tests were performed by the axial compression testing machine (AG-IS 10 kN, Shimadzu Corporation, Kyoto, Japan). In the study, two groups (intact and operated) (Figure-1.a) were biomechanically tested preoperatively and postoperatively in order to observe the original mobility of the spinal segment and to compare the differences after the surgery. The first biomechanical test was conducted pre- and postoperatively in a neutral position with an axial 129 compression of 400 Newtons. After that, the tests were carried out by 8400 Nmm moments in different positions, such as flexion, extension, and right-left bending positions (Figure-1.b,c,d). A specially designed device was used to increase moments up to 8400 Nmm, which was generated through the axial movement of the actuator and applied to each of the specimens to achieve the flexion and extension motions in the form of right and left-bending, respectively[9,17].

During the biomechanical test period, the intervertebral displacement at the subjected levels (L4-L5) was recorded in real time by an extensometer. The displacement value data was evaluated by the Wilcoxon Signed Rank test through software (SPSS 15.0) for Windows.

RESULTS:

The median displacement values of the biomechanical study are shown in Table I. The median displacement values of the intact spines of 10 specimens for each position of the axial compression test, the compression test in flexion, the extension motions and the right-left bending positions in the intact specimens were 3.70 mm, 3.40 mm, 2.44 mm, 2.72 mm and 3.21 mm, respectively (Figure-2).

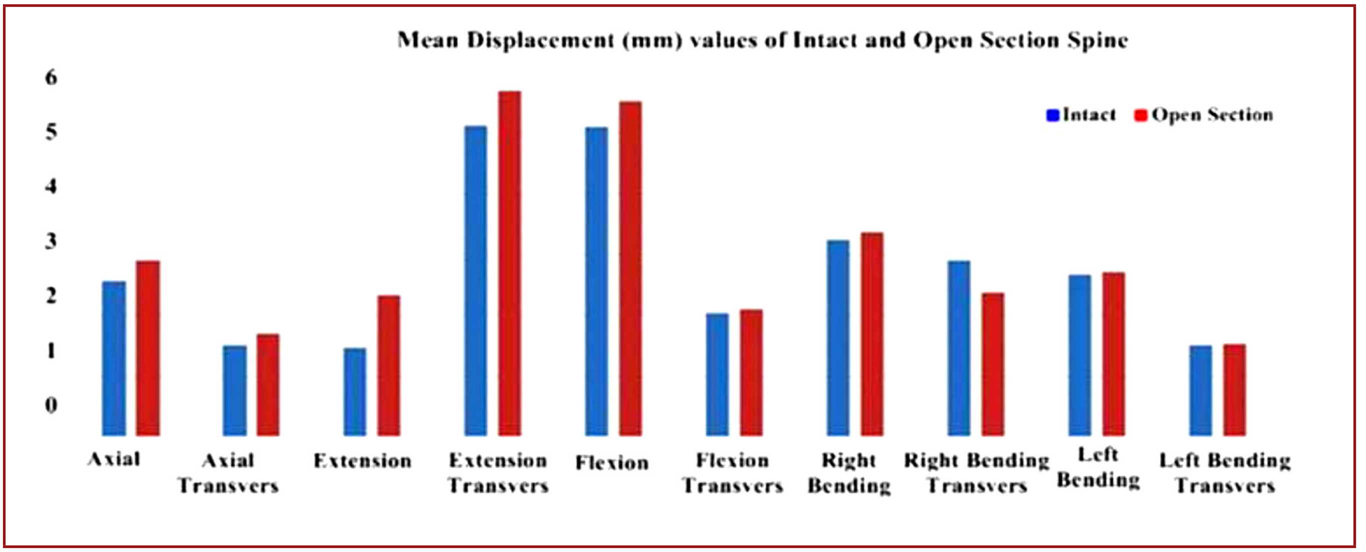

Figure-2. Mean displacement values for both intact and open discectomized lamb spines groups

After performing the open left hemilaminectomy discectomy for each lamb spine, the median values of the measurement results of the current biomechanical study were obtained (Table-1). The median displacement values of the discectomy lamb spines of each specimen for each position of axial compression test, compression test in flexion, extension motions and right-left bending positions were 2.85 mm, 5.43 mm, 2.68 mm, 3.69 mm and 4.53 mm, respectively.

Table-1. Displacement values in mm's in various motional positions

	Axial	Axial transverse	Extension	Extension transverse	Flexion	Flexion transverse	Right bending	Right bending transverse	Left bending	Left bending transverse
Mean values (n=10) of infact Lumbar Lamb Spine test	3,7022	2,6877	2,4416	6,2273	3,4084	1,4839	2,7230	4,5369	3,2176	4,4491
Mean values (n=10) of open unilateral laminectomized Lumbar Lamb Spine test	2,8525	3,1305	2,6825	5,7239	5,4314	1,9112	3,6928	3,0334	4,5392	2,7581

The displacement results for the two phases of this study were statistically compared. A significant change was found between the displacement values of specimens under compression in extension (P=0.013), and anterior posterior and axial displacement in the left-bending positions respectively (P=0.034, P=0.010). There were no statistically significant changes under the axial compression test, compression test in flexion motion and the right-bending position for both groups.

DISCUSSION:

In recent decades, discectomy has become the gold standard technique in symptomatic lumbar herniated disc patients who do not respond to conservative treatment modalities. In our study, we attempted to determine the biomechanical stability of the lumbar spine after unilateral discectomy. Detwiler et al[6] found that, compared with the intact condition, a total laminectomy including bilateral facets in treated human specimens had significantly larger increases in angular motion during flexion, lateral bending, and axial rotation than their facet- sparing laminectomy-treated human specimens. Therefore, a facet-163 sparing laminectomy produces less biomechanical instability than a total laminectomy including bilateral facets[6].

In our study, since hemilaminectomy was only performed on the left side, only a significant change was found between the displacement values of the specimens under compression in extension, and anterior-posterior and axial displacement in the left-bending positions. There were no significant differences between the intact spine and the unilateral laminectomy discectomy spine in other positions. Left-bending displacement is thought to be significant, due to the left-side laminectomy that was performed because ligamentum flavum was removed from the left side but the right side was intact.

Karakaşlı et al.[9] showed that after endoscopic discectomy only the anteroposterior displacement values of the left-bending test were statistically significant. Recent studies indicate that there was instability and mobilization at the laminectomy side. Lu et al.[13] reported that a 2-level total laminectomy and discectomy affected the flexion instability of the spine. In our study, there was no significant difference in the spine following the partial laminectomy, the discectomy spine and the intact spine at the flexion position. The extension displacement positions were found to be statistically significant because, after the total discectomy, there was laxity at the annulus ligaments. This laxity, which causes instability at the vertebral segment, results in displacement during extension. In our study there was no displacement in flexion because the facet joints were intact and prevented flexion displacement. As a result of this sclerosis occurred at the end plates and movement decreased in the long term.

Schulte et al.[16] reported that, there were increased movements of 26%, 6% and 12% following discectomy at flexion- extension, lateral bending and axial rotation, respectively. Bischop et al.[4] found that the range of motion (ROM) at the level of the laminectomy increased significantly for flexion and extension (7.3%), lateral bending (7.5%), and axial rotation (12.2%), but the ROM of the adjacent segments was only significantly affected in lateral bending. Previous studies showed that an increased range of motion causes instability. In the literature, clinical studies reported that, after a laminectomy discectomy, instability increases in the vertebra segment during the early period and decreases during the late period[7,8].

In our study, during flexion there was no increase in displacement, but during extension, displacement was significantly increased. After a total discectomy, laxity occurred at the mobile segment, but in flexion movements, displacement was limited by facet joints. During extension movements, facet joint limitations were reduced so displacement increased. Lu et al.[13] demonstrated that multilevel fenestrations (bilateral L3-4, L4-5, L5-S1 laminectomy) and (L4-5, L5-S1) discectomies affect lumbar spinal stability in flexion, but they have no effect on the stability of the lumbar spine in lateral bending or axial rotation.

Anasetti et al.[2] compared the ROM of human cadaver L4-5 segments with or without a resected supraspinous ligament (SSL) after implanting an interspinous device. After resecting the SSL, the authors found a higher ROM during flexion–extension than the intact spine. Tai et al.[17] compared the intervertebral disc displacement of human cadaver L4-5 segments during flexion–extension after two decompression procedures. In one group, a laminatomy with SSL preservation was performed, and a laminectomy with flavectomy and resection of the SSL was performed in the other. During flexion, the intervertebral disc displacement was higher after resecting the SSL (17).

Jia et al.[8] used 3 sheep models: Group 1, laminectomy only; group 2, laminectomy plus left total facetectomy; and group 3, laminectomy plus bilateral facetectomy and they found that the lumbar stability in flexion/extension and torsion was severely decreased after the three types of surgery. However, in group 1 and 2, each parameter had returned to normal levels by 12 weeks. Lu et al.[13] showed that after open discectomy at L4- L5 and L5-S1, additional signs of movement (3.94 mm anteroposteriorly and 2.5 mm vertically) were found at L4-L5. A notably large increase in vertical motion (2.98 mm) was seen at L5-S1. The motions in the anteroposterior translation showed no statistically significant difference between the intact surgically managed states. In the vertical translation, the motions after different levels of surgery increased significantly at the L4-L5 and L5-S1 segments. Under the combined shear and flexion loads, the translations in the antero-posterior directions ranged from 3 to 4 mm. In the vertical direction, the absolute ROM was always less than 3 mm, even with significant increases after surgery. In addition, it was found that the segmental motion was redistributed after operation. Postoperative motions at L3-L4, L4-L5 and L5-S1 showed an increase in vertical translation, suggesting a redistribution of motion range within the whole lumbar spine after surgery[13,15].

In our study, the displacement values of partial laminotomy and total discectomy spine specimens were similar to studies in the literature. During flexion of 5mm and extension of 2.6 mm, right bending of 3.7 mm has been found. Extension and left-lateral bending values were statically significant in comparison to an intact spine (P=0.013, P=0.034, respectively).

Lee et al.[11] reported that, in flexion/extension, bilateral laminotomies resulted in an average increase in L2–L5 range of flexion/extension motion of 14.3 %, whereas a full laminectomy resulted in an increase of 32.0 %. These results suggest that laminectomy can cause more instability than bilateral laminotomy. Tai et al.[17] found in the porcine model that instability of the lumbar spine following laminectomy was significantly greater than that of the lumbar spine in intact form or following a bilateral laminotomy.

In conclusion, biomechanical instability has been shown in a partial laminectomy and total discectomy spine during extension and partial laminectomy side-bending movements. After a total discectomy, a reduction in annulus fibrosis tension caused laxity at the mobile spine segment. Increased mobilization caused instability at the spinal mobile segment.

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