BIOMECHANICAL COMPARISON OF INTACT LUMBAR LAMP SPINE AND ENDOSCOPIC DISCECTOMIZED LAMP SPINE

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ABSTRACT

Objectives: Purpose of current study was biomechanical comparison of changes wrought on motion segments after minimally invasive percutan endoscopic discectomized and intact spine.
Materials and Methods: We prepared ten fresh-frozen lamb spines were used for this study. The spine of each specimen was dissected between L4-L5. The biomechanical tests for both intact spine and discectomized spine were performed by using axial compression testing machine (AG-I 10 kN, Shimadzu, Japanese). The axial compression was applied to all specimens with the 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 by a specially designed fixture.
Results: In axial compression and flexion tests, the specimens were more stable according to displacement values. The displacement values of sectioned specimens were closer to intact specimens. Only displacement values of left-bending anteroposterior test for both situations were significant (0.05 ≥ P).
Conclusion: PTED hasn’t biomechanical and cilinical disadvantages. Endoscopic discectomy hadn’t any disadvantages in stability. Only anterior-posterior displacement values of left bending test were statistically significant. We consider that cause of these results were due to the fact that all specimens had percutan transforaminal endoscopic discectomy (PTED) from left side.

Keywords: Intact spine; endoscopic discectomy; biomechanics

ÖZET

Amaç: Bu çalışmanın amacı, minimal invaziv perkütan disektomi sonrası omurganın hareketli segmentinin biyomekanik değişikliklerinin sağlam omurga ile karşılaştırılmasıdır.
Gereç ve Yöntemler: Bu çalışmada on adet taze donmuş kuzu omurgası hazırlanmıştır. Her bir omurgaya L4-L5 seviyesinde perkütan endoskopik disektomi yapılmıştır. Sağlam ve endoskopik disektomi yapılmış omurgalar için biyomekanik test aksiyel kompresyon test makinesi ile gerçekleştirilmiştir (AG-I 10 kN, Shimadzu, Japanese). Tüm örneklere aksiyel kompresyon 5 mm/dk hız ile uygulanmıştır. Her bir omurgaya, özel tasarlanmış bir aparatla, 8400 N/mm moment fleksiyon, ekstansiyon, sağa eğilme ve sola eğilme hareketlerinde uygulanmıştır.
Bulgular: Aksiyel kompresyon ve fleksiyon testlerinde yer değiştirme bulgularına göre örnekler daha stabildir. Disektomi yapılmış omurgaların yer değiştirme değerleri, sağlam omurgaların değerlerine yakındır. Her iki grup karşılaştırıldığında, sadece sola eğilme ön-arka kayma değerleri anlamlı çıkmıştır (0.05 ≥ P).
Sonuç: Endoskopik perkütan disektominin, biyomekanik ve klinik açıdan dezavantajı yoktur. Endoskopik disektomi stabilite yönünden herhangi bir dezavantaja sahip değildir. Sadece sola eğilmede öne arka kayma değerleri istatistiksel olarak anlamlı bulunmuştur. Bu sonuçların sebebini tüm omurgaların sol taraftan disektomi yapılmış olmasına bağlamaktayız.

Anahtar Sözcükler: Sağlam omurga; endoskopik disektomi; biyomekanik

1. INTRODUCTION

Lumbar discogenic radicular pain secondary to lumbar disc prolapse, protrusion, or herniation accounts for less than 5% of low back problems. However, disc abnormalities constitute the most common causes of nerve root pain.[1] The intervertebral disc, in accordance with its mechanical requirements, is an organized, independent cell unit. One of its main functions consists of dampening compressive loads.[2] 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. On physiologic activities, the intervertebral discs are exposed to various and complex mechanical loadings.[3] In symptomatic patients, failure of nonoperative management usually results in surgical intervention.

Lumbar discectomies are often performed to decompress the nerve root and alleviate radicular pain in cases of failed conservative therapy. The primary goal of surgical treatment is the relief of nerve root compression by removing the herniated nuclear material and the primary modality of treatment has been open discectomy. Surgical success in treatment of spinal deformities depends on several factors such as approach (anterior/posterior/both), release techniques.[4] However, the specific pathology often determines the most suitable procedure. Extruded and sequestered disc herniations may require more invasive procedures to retrieve the disc material, whereas disc protrusions are potentially more amenable to minimally invasive percutaneous procedures.[5] The full-endoscopic transforaminal operation with posterolateral access evolved out of this[6] the technique of percutaneous endoscopic transforaminal lumbar discectomy (PTED) has evolved over the years and is increasingly becoming a preferred choice of treatment for the management of lumbar disc herniation. PTED, by virtue of its transforaminal approach, offers several advantages over open methods like protection of posterior ligamentous and bony structures, lesser postoperative instability, facet arthropathy, and disc space narrowing. Also, there is no interference of the epidural venous system that may lead to chronic neural edema and fibrosis.[7]

Many authors think that the stability of spine is preserved because the anatomical components of the spine are not damaged after PTED. However, careful review of literature revealed not adequate biomechanical study on PTED. So we conducted present study focused on a biomechanical comparison of the changes wrought on motion segments after a minimally invasive endoscopic discectomy and intact spine. On behalf of PTED, we wish to prove it hasn't any instability in the aspect of biomechanics.

2. MATERIALS AND METHODS

2.1 Specimens

Ten fresh-frozen lamb spines were used for this study. The ages of lambs were six-twelve months. The specimens have not macroscopic and radiological diseases. Sacrum from T12 parts of the spine of each specimen was dissected. All of the specimens were frozen and thawed before tests during one night at room temperature. All of the specimens were potted with cement at the T12 vertebra and sacrum part.

2.2 Surgery Method

All specimens are then bluntly fenestrated from disc annulus of L4-L5 with the obturator. A 7-mm beveled cannula is then advanced over the obturator and docked within the annular fibers. The obturator typically enters the disc at a 25- to 35-degree angle in relation to the coronal plane and is parallel to the end plates. The obturator is removed and replaced by the operating endoscope. The endoscopic rongeurs placed down the working channel of the endoscope. And microdiscectomy operation was carried out.[5,6] All specimens were operated on left side.

2.3 Test Machine

The biomechanical tests were performed by using the axial compression testing machine (AG-I 10 kN, Shimadzu, Japanese). Test machine consisted of load cell (max. 5 kN) attached to crosshead of main body, compression plates (upper plate and lower plate), adapter for compression include screw, table (support) of bending and controller. The test device had data processing software TRAPEZIUM2 and CCD camera extensometers (Non-contact Video Extensometer DVE-101/201, Shimadzu, Japanese) which was the elongation meter that enables elongation measurement without making contact with the test specimen. The two non-contact cameras grabbed image of the gauge marks attached to the test specimens processed the gray-scale image and performed non-contact measurement of displacement of the gauge marks to measure the elongation of the test specimen.

2.4 Biomechanical Tests

The current study was conducted in two groups. The spines were load tested in the following sequence: 1) Load testing of the intact spine before any manipulation. 2) Load testing after PLED of spine from L4-L5. In the axial neutral position 400N axial compression loads were applied to each specimen in both groups (Figure 1). A specially designed fixture used to increase moment up to 8400 Nmm generated through the axial movement of the actuator was applied to each specimen to achieve the flexion (Figure 2) and extension motions, right and left bending (Figure 3, 4), respectively.[8] During biomechanical test period, intervertebral displacement at decompression levels L4-L5 was recorded continuously by extensometer. While preparing test specimens, suitable gauge marks (diamond mark for high accuracy) were selected for the test specimen. Gauge marks were applied to test specimen with pins due to sliding surface of the specimen. Gauge marks were attached to L4 and L5 to measure the superior-inferior and anterior-posterior displacement. The two non-contact cameras grabbed image of the gauge marks. Personal computer processed the gray-scale image and measured displacement of the gauge marks of each camera image to measure the elongation of the test specimens. The gauge mark displacement on the CCD screen was converted into actual displacement. The displacement values were recorded on personal computer connected with test machine and two non-contact cameras. The data of displacement values was evaluated with Wilcoxon Signed Rank test by software (SPSS 15.0 for Windows).

3. RESULTS

In current study, at first phase, 400 Newton axial loads were applied to intact spine for neutral position and 8400 Nmm moments were applied to intact spine for flexion and extension motions, right and left bending positions. Resultant displacement values of biomechanical study were shown in Table I. Median displacement values of intact spine of ten specimens for each position of axial compression test, compression test in flexion, extension motions and right, left bending positions in intact specimens were 3.64 mm, 6.73 mm, 1.07 mm, 3.37 mm and 2.37 mm respectively (Figure 5). After endoscopic discectomy for each lamb spine measurement results of current biomechanical study were shown in Table II. Median displacement values of discectomy lamb spine of each specimens for each position of axial compression test, compression test in flexion, extension motions and right, left bending positions were 3.76 mm, 6.69 mm, 1.34 mm, 4.76 mm, 3.01 mm respectively (Figure 5). Displacement results for two phases of this study were compared statistically. A significant change was found between displacement values of specimens under compression only in left bending position ($P = 0.047$). There weren't any statistically significant changes in position of axial compression test, compression test in flexion, extension motions and right bending position for both groups.

4. DISCUSSION

Each spinal segment consists of an anteriorly situated intervertebral disc and small, paired, posterior synovial joints (facet joints) comprising a "three-joint complex".[9] Discectomy (or nucleotomy) in animal models and human cadaver studies demonstrates changes similar to those that occur in early human disc degeneration, supporting the use of this in vitro model system.[10] The physiologic disc exhibited a clear convex inner and outer annular bulge under loading, both in the anterior and posterior regions. Unlike the inner annulus of the physiologic disc, the inner annulus of the nucleotomy displayed a concave bulge. The partial nucleotomy also displayed a reduction in inner annulus bulge, with little movement of the inner annulus-nucleus interface from its unloaded position. The partial nucleotomy exhibited outer convex bulging but to a smaller degree than the physiologic disc.[11]

In our study since only fragmentectomy is performed in PTED, the disc height is preserved. The displacement values, in this study, didn't show any changes during axial loading compared to intact spine. There weren't any statistically significant changes during axial loading in both groups. Axial displacement median values of intact spine and percutan transforaminal endoscopic discectomized spine were 3.64 mm and 3.76 mm respectively.

The annulus fibrosus and nucleus pulposus have distinctly different anatomical morphology, biochemical composition, and biomechanical characteristics.[12, 13] It is the unique interaction between the solid matrix and interstitial fluid, which provides the disc with the strength and flexibility necessary to withstand the large motions the spine undergoes during even normal daily activities.[14]

The kinematics and load-deformation relationships of the spine were minimally altered after microdiscectomy. Small increases occurred in ROM, and lateral bending flexibility. Hence, microdiscectomy does not overtly destabilize the spine. Clinically, prophylactic fusion is not recommended after microdiscectomy unless clinical evidence of instability exists or unless there is structural loss of other spinal elements (e.g., prior laminectomy or facetectomy).[15]

Our study was conducted *in vitro*. After PTED *in vivo* and *in vitro* biomechanical effects cannot be documented. However, we can document in vitro biomechanical changes. A small window is opened and only the disc fragment is removed in annulus fibrosis after PTED. A significant statistical instability was observed 4.45mm displacement values anteroposterior direction under left bending load. In all the specimens PTED was performed on the left side. Therefore, in our opinion, there was a significant (P = 0,047) change in antero-posterior displacement during left bending.

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.[16]

The technique of percutaneous transforaminal endoscopic lumbar discectomy (PTED) has evolved over the years and is increasingly becoming a preferred choice of treatment for the management of lumbar disc herniation. PTED, by virtue of its transforaminal approach, offers several advantages over open methods like protection of posterior ligamentous and bony structures, lesser postoperative instability, facet arthropathy, and disc space narrowing Also, there is no interference of the epidural venous system that may lead to chronic neural edema and fibrosis.[7, 17, 18] (PTED) is a minimally invasive procedure that preserves the stabilizing elements of the spine and avoids epidural scar formation.[6, 19]

In this study, the displacement values measured under loading after PTED and on the intact spine were similar to each other. There isn't a serious damage in the disc following PTED. At the same time, because there is no damage in the posterior components, the displacement values measured were similar to those of the intact spine, except for the antero-posterior displacement values of PTED side bending (Table I, II).

Lu, W. W et al showed that the motions in the x direction (anteroposterial translation) showed no statistically significant difference between the intact and surgically managed states, except at L4-L5. In the y direction (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 anteroposterior directions ranged from 3 to 4 mm. In the vertical direction, the absolute range of motion was always less than 3 mm, even with significant increases after 0pen surgery. In addition, it was found that the segmental motion was redistributed after operation. Post-operation motions at L3-L4, L4-L5, and L5-S1 showed increase in vertical translation. In contrast, motion at L2-L3 (left intact) decreased, suggesting a redistribution of motion range within the whole lumbar spine after surgery.[16] In position of lateral bending, the motions in each segment increased after fenestration and discectomy.[16]

The denucleated disc showed a lower intradiscal pressure (IDP) than the normal disc.[20] Nucleotomy alters the magnitude of radial and axial AF strains. Increased strains may make the AF vulnerable to fatigue damage.[21] The outer AF bulge was not altered by nucleotomy. The inner AF bulge remained outward but is significantly decreased in the neutral position after nucleotomy porcine model of extensive nucleotomy by fenestration of the AF, which resulted in early and severe disc degeneration with considerable endplate damage.[22]

In our study only anterior-posterior displacement values of left bending test were statistically significant. We consider that the cause of these results were due to the fact that all the specimens had PTED from the left side. PTED has biomechanical and clinical advantages.

It still has been disadvantages; safe and effective access is limited to a narrow channel and there is little or no working space, as compared with conventional open surgery.[23,24] The limitation of this study was the effects of surrounding musculature and soft tissues were not taken into account.[25] And other limitation was the specimens didn't have living tissue, the study was conducted *in vitro*.

Although efforts have been made to simulate the clinical conditions, there are certain limitations to this study. Under laboratory environment, this experimental study use lamb lumbar spine instead of human cadaveric spines. Although physiological structures such as spinal alignment, number of lumbar segments of the lamb spines are somewhat different from those of human cadaveric spines, however, animal spines are the most convenient choice to perform the experiment with long spinal segments on circumstance that human cadaveric spines cannot be accessed. Investigation on the effects of other loading conditions such as axial rotation might be necessary in the future.

In conclusion, only anterior-posterior displacement values of left bending test were statistically significant. PTED has not any disadvantages in the aspects of biomechanics and clinic. Understanding biomechanical instability of spine in PTED will shed light on choice of surgical techniques and indications for surgery.

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