Cranially migrated lumbar intervertebral disc herniations: A multicenter analysis with long-term outcome

ABSTRACT

Objective: Risk factors of cranial migration were investigated in patients with lumbar disc herniation (LDH) that migrated in the cranial direction and the long-term outcomes are discussed in this study.

Materials and Methods: Patients who underwent surgery for LDH at four different centers between 2012 and 2017 were studied. Extraligamentous discs were located in the lateral part of the posterior longitudinal ligament (PLL) within the spinal canal of the axial plane, and subligamentous discs were located under the PLL. The extent of cranial migration was calculated as a percentage of the height of the migrated corpus. Based on the extent of cranial migration, partial hemilaminectomy or hemilaminectomy was performed at different rates in each patient and the amount of laminectomy performed was recorded. During surgery, all free fragments were attempted to be removed. The appropriate technique was decided intraoperatively, and the surgery was performed on an individual patient basis.

Results: Of 1289 patients who underwent surgery for LDH, 654 (50.73%) had caudal migration, 576 (44.68%) had migration at the level of the disc, and 59 (4.57%) had cranial migration. Analysis of 59 patients with cranial migration according to the localization of the disc fragment revealed that 31 had extraligamentous and 28 had subligamentous fragments (P = 0.024).

Conclusions: Extraligamentous intervertebral disc fragments migrate more cranially than subligamentous intervertebral fragments. The anatomy of the PLL that varies along the corpus is the main reason for the weakness of the resistance of the disc material to the dorsolateral region, direction of discrete force vectors, and orientation of the disc fragment due to torsional vertebral movements.

Keywords: Caudal, cranial, direction, intervertebral, lumbar disc

INTRODUCTION

Lumbar disc herniation (LDH) is one of the most common causes of low back and leg pain. Currently, microdiscectomy is the most frequently performed spinal surgery. The intervertebral disc anatomy was described first by Vesalius in the 15th century, and the first disc surgery reported by Dandy, at the beginning of the 1930s, was done to treat two sequestrated discs causing neural compression.[1,2] From this date, spine surgeons have demonstrated promising results of disc surgery using technological advances in imaging and different techniques, especially microsurgical procedures.

Proper patient selection, effective imaging method for diagnosis, and surgical technique are the most important factors determining postoperative success in a patient undergoing lumbar microdiscectomy. The patient’s neurological status and localization of the

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fragment (median, lateral, far lateral, and so forth) are the most important factors determining the method of disc surgery to be applied.

Theoretically, fragments from the intervertebral disc space may migrate in cranial, caudal, lateral, anterior, or posterior directions. However, it is obvious that the surgical technique will vary according to the localization of the herniated disc material. In this multicenter and large series study, risk factors were investigated in patients with LDH and cranial migration. We attempted biomechanically to determine the possible causes of cranial migration and discussed the importance of the surgical technique to be applied.

MATERIALS AND METHODS

Patient selection
After approval by the local ethics committee, patients who underwent surgery for LDH at four different centers between 2012 and 2017 were reviewed retrospectively. Patients who underwent multilevel discectomy or reoperation for recurrent LDH and those with antero- or retro-listhesis accompanying disc herniation were excluded from the study. Patient’s demographic data, preoperative neurologic findings, disc level, localization and side of the operation, presence of intraoperative dural tear, postoperative recurrence rate, and postoperative follow-up were recorded.

Preoperative sagittal and axial lumbar magnetic resonance (MR) images were examined and categorized according to the classification defined by Fardon et al.[3] Cranial migration was examined in detail. The extent of migration to the cranial region was calculated as a percentage of the height of the migrated corpus [Figure 1].

Classification of herniated disc localization according to the posterior longitudinal ligament
Herniated discs located in the lateral part of the posterior longitudinal ligament (PLL) within the spinal canal were classified as extraligamentous and those under the PLL were classified as subligamentous on the axial MR image [Figure 2].

Surgical technique
All patients were operated on by expert neural spine surgeons. The operation was performed with the patient under general anesthesia and in the prone position. After leveling with fluoroscopy, a midline incision was made. Skin, subcutaneous fat, and paravertebral muscle fascia were crossed and classified according to the amount of hemilaminectomy performed after subperiosteal muscle dissection. Type I (1/2 partial hemilaminectomy), Type II (2/3 partial hemilaminectomy), and Type III (hemilaminectomy) surgery was in patients with cranial migrations [Figure 3]. The relationship between the amounts of hemilaminectomy and cranial migration was examined. The choice of surgical technique was not considered according to sex, age, or side. All free fragments were intended to be removed intraoperatively. One of the aforementioned three techniques was chosen on an individual patient basis.

In addition, data on patients with cranial migration were recorded in terms of intraoperative dural tear, neural injury, and recurrent LDH.

Statistical analysis
SPSS (Statistical Package for Social Sciences) v21.0 software (IBM Inc., Armonk, New York, USA) was used for statistical analysis of the data obtained. A t-test was used for statistical analysis of parametric data. The Chi-square test was used for analysis of percentile data, and correlation and variance

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Figure 1: Measurement of migration rate of the intervertebral disc fragment to corpus length

Figure 2: Illustration of the superficial and deeper layers of the posterior longitudinal ligament
analysis were used to reveal relationships between results. The level of significance in the 95% confidence interval was accepted as $P < 0.05$.

**RESULTS**

Lumbar microdiscectomy was performed in 1421 patients. A total of 132 patients were excluded from the study (61 underwent multilevel or bilateral microdiscectomy, 37 had recurrent LDH, and 34 had LDH accompanied by spondylolisthesis). Of the remaining 1289 patients studied, 654 (50.73%) had caudal migration, 576 (44.68%) had herniation at the level of the disc, and 59 (4.57%; 36 males and 23 females) had cranial migration ($P > 0.05$; Figure 4). There was no statistically significant difference between sex and cranial migration of the herniated disc ($P > 0.05$). The mean patient age was 47.8 years [minimum, 23; maximum 79; Table 1].

The cranial migration rates of the herniations were 11.7% (2/17), 5.7% (2/35), 8.8% (9/102), 3.1% (19/616), and 5.2% (27/519) at the L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1 levels, respectively [not significantly different, $P > 0.05$; Table 2]. Cranial migration occurred on the left side in 34 patients and the right side in 25 patients (not significantly different, $P > 0.05$).

The extent of cranial migration of the disc fragment relative to the corpus length was 100% (a corpus height) in 16 patients (15 sequestrated, 1 extruded), 75%–100% in 5 (all sequestrated), 50%–75% in 13 (11 sequestrated, 2 extruded), and 25%–50% in 25 (3 sequestrated, 22 extruded). There was a significant correlation between cranial migration and sequestration ($P < 0.05$). It was noteworthy that 32 of the 34 patients with <50% migration had sequestrated disc herniations. The presence of <50% cranial migration in the sequestrated discs was statistically significant ($P = 0.00$). Of 25 extruded disc herniations, cranial migrations accounted for <50%.

Extraligamentous fragmentation occurred in 1008 patients studied according to the anatomic position of the PLL, 31 of 59 with cranial migration, 130 of 654 with caudal migration, and 31 with migration at the level of the disc, whereas subligamentous fragmentation was noted in 281, 28 of 59 ($P = 0.24$), 524 of 654, and 545, respectively [Table 3]. Cranial and caudal migration occurred significantly more often with extraligamentous fragments ($P = 0.001$).

Type I surgery was performed in 35 patients with cranially migrated discs (cranial migration rates, 25%–50% in 25, 50%–75% in 9, and 100% in 1), Type II surgery in 21 (75% in 4, 75%–100% in 4, and 100% in 13), and Type III surgery in only 3 (all 100%). There was no correlation between cranial migration and hemilaminectomy amount ($P < 0.05$). Only two patients (3.3%) with cranial migration had motor deficits preoperatively, and both had a complete recovery after 1 month of postoperative physical therapy. None of the other patients had any motor loss before or after surgery. An intraoperative dural tear was detected in one patient (1.6%). Primary dural repair was performed and no cerebrospinal fluid fistula was observed postoperatively. In patients with migration at the level of the disc and with caudal migration, the preoperative motor deficit rate was 6.5% and the dural tear rate was 4.8%.

No patient with cranial migration had recurrence during the mean follow-up of 38 months, while the recurrence rate was 3.1% in patients with migration at the level of the disc and with caudal migration.
Table 1: Patient demographics and detailed analysis of the cranially migrated discs

| Patients | Gender | Age  | Side of disc | Level of disc | Localization of the disc according to PLL | Classification of the disc | Rate of cranial migration (%) | Follow-up (month) |
|---------|--------|------|--------------|---------------|------------------------------------------|---------------------------|--------------------------------|------------------|
| 1       | Male   | 31   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 50-75                          | 60               |
| 2       | Male   | 38   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 60               |
| 3       | Female | 53   | Right        | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 59               |
| 4       | Female | 41   | Left         | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 58               |
| 5       | Male   | 35   | Right        | L5-S1         | Extraligamentous                         | Extruded                  | 50-75                          | 58               |
| 6       | Male   | 31   | Right        | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 58               |
| 7       | Male   | 36   | Right        | L5-S1         | Extraligamentous                         | Extruded                  | 50-75                          | 58               |
| 8       | Male   | 46   | Left         | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 57               |
| 9       | Female | 37   | Left         | L5-S1         | Subligamentous                           | Sequestrated              | 50-75                          | 57               |
| 10      | Female | 53   | Right        | L3-L4         | Extraligamentous                         | Sequestrated              | 100                            | 56               |
| 11      | Male   | 35   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 56               |
| 12      | Male   | 61   | Left         | L3-L4         | Extraligamentous                         | Sequestrated              | 100                            | 55               |
| 13      | Female | 38   | Left         | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 54               |
| 14      | Male   | 38   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 53               |
| 15      | Male   | 49   | Left         | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 53               |
| 16      | Male   | 31   | Left         | L1-L2         | Subligamentous                           | Extruded                  | 25-50                          | 52               |
| 17      | Male   | 56   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 50-75                          | 51               |
| 18      | Male   | 46   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 50               |
| 19      | Female | 73   | Left         | L3-L4         | Subligamentous                           | Extruded                  | 25-50                          | 50               |
| 20      | Male   | 36   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 50               |
| 21      | Male   | 33   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 48               |
| 22      | Male   | 23   | Right        | L4-L5         | Extraligamentous                         | Sequestrated              | 50-75                          | 48               |
| 23      | Male   | 58   | Right        | L3-L4         | Extraligamentous                         | Sequestrated              | 100                            | 48               |
| 24      | Female | 41   | Left         | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 47               |
| 25      | Male   | 51   | Right        | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 47               |
| 26      | Male   | 67   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 47               |
| 27      | Female | 46   | Right        | L5-S1         | Subligamentous                           | Extruded                  | 25-50                          | 47               |
| 28      | Female | 53   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 100                            | 46               |
| 29      | Female | 59   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 46               |
| 30      | Male   | 57   | Left         | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 46               |
| 31      | Female | 41   | Left         | L3-L4         | Extraligamentous                         | Sequestrated              | 100                            | 44               |
| 32      | Male   | 61   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 43               |
| 33      | Female | 53   | Right        | L5-S1         | Subligamentous                           | Sequestrated              | 25-50                          | 41               |
| 34      | Female | 66   | Right        | L4-L5         | Subligamentous                           | Extruded                  | 25-50                          | 38               |
| 35      | Female | 34   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 50-75                          | 37               |
| 36      | Female | 38   | Left         | L5-S1         | Subligamentous                           | Extruded                  | 50-75                          | 32               |
| 37      | Male   | 42   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 31               |
| 38      | Female | 79   | Left         | L1-L2         | Extraligamentous                         | Sequestrated              | 100                            | 30               |
| 39      | Female | 56   | Right        | L3-L4         | Subligamentous                           | Sequestrated              | 25-50                          | 29               |
| 40      | Male   | 65   | Left         | L3-L4         | Extraligamentous                         | Sequestrated              | 75-100                         | 27               |
| 41      | Male   | 46   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 50-75                          | 25               |
| 42      | Female | 57   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 50-75                          | 24               |
| 43      | Male   | 56   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 100                            | 23               |
| 44      | Male   | 62   | Left         | L2-L3         | Subligamentous                           | Sequestrated              | 50-75                          | 22               |
| 45      | Female | 65   | Right        | L5-S1         | Subligamentous                           | Sequestrated              | 25-50                          | 20               |
| 46      | Male   | 56   | Right        | L3-L4         | Extraligamentous                         | Sequestrated              | 100                            | 20               |
| 47      | Male   | 46   | Left         | L4-L5         | Extraligamentous                         | Sequestrated              | 50-75                          | 18               |
| 48      | Male   | 69   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 75-100                         | 18               |
| 49      | Female | 44   | Left         | L5-S1         | Extraligamentous                         | Extruded                  | 100                            | 17               |
| 50      | Female | 56   | Left         | L4-L5         | Subligamentous                           | Sequestrated              | 50-75                          | 16               |
| 51      | Female | 48   | Left         | L2-L3         | Extraligamentous                         | Sequestrated              | 100                            | 15               |
| 52      | Male   | 43   | Left         | L5-S1         | Extraligamentous                         | Sequestrated              | 100                            | 14               |

Contd...
What factors affect cranial migration of the disc fragment? To our knowledge, no specific studies have addressed factors that determine the surgical technique and affect the localization and direction of the disc fragment are important factors that determine the surgical technique and affect the results. Only a few studies with a limited number of cases have reported on the direction of disc fragments. In our current study, the fragment that migrated cranially or caudally was much higher when it originated from the lateral direction. In addition, we believe that the corpus pedicle has a barrier effect against the caudal direction of the lateral origin of disc herniation. It is known that a strong segmental deep PLL layer with a mean thickness of 10 mm, extends 5 mm to both sides of the midline. When the axial width of the PLL is considered to be 10 mm, there is approximately 7 mm of extrapoligamentous space on both sides (Figure 5).

It is noteworthy that cranial or caudal migration was more frequent in our study. This result supported the relationship between the migration of the disc fragment to the cranial or caudal direction and the anatomical structure of the PLL. In our study, cranial migration of extrapoligamentous localized disc fragments was significantly more frequent than cranial migration. This difference suggested that the direction of force vectors leading to the disc herniation is important beyond the localization of the disc. It is clear that the static and dynamic morphological structure of the lumbar spine also influences the direction of migration. The pressure generated

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### Table 1: Contd...

| Patients | Gender | Age | Side of disc | Level of disc | Localization of the disc according to PLL | Classification of the disc | Rate of cranial migration (%) | Follow-up (month) |
|----------|--------|-----|--------------|---------------|-------------------------------------------|----------------------------|-----------------------------|------------------|
| 53       | Male   | 34  | Right        | L4-L5         | Extraligamentous                          | Sequestrated               | 75-100                      | 14               |
| 54       | Male   | 48  | Right        | L3-L4         | Extraligamentous                          | Extruded                   | 25-50                       | 13               |
| 55       | Male   | 51  | Right        | L5-S1         | Subligamentous                            | Extruded                   | 25-50                       | 12               |
| 56       | Female | 50  | Left         | L5-S1         | Subligamentous                            | Extruded                   | 25-50                       | 11               |
| 57       | Male   | 28  | Right        | L5-S1         | Subligamentous                            | Extruded                   | 25-50                       | 11               |
| 58       | Male   | 37  | Left         | L5-S1         | Extraligamentous                          | Sequestrated               | 75-100                      | 10               |
| 59       | Male   | 40  | Right        | L4-L5         | Extraligamentous                          | Sequestrated               | 75-100                      | 10               |
| Mean     |        | 48  |              |               |                                           |                            |                             | 38               |

**PLL:** Posterior longitudinal ligament

### Table 2: Analysis of the intervertebral levels where cranial migrations are observed

| Levels       | Cranial migration cases, n (%) | P   |
|--------------|-------------------------------|-----|
| L1-L2        | 2/17 (11.7)                   | 1.56|
| L2-L3        | 2/35 (5.7)                    | 1.31|
| L3-L4        | 9/102 (8.8)                   | 1.11|
| L4-L5        | 19/616 (3.1)                  | 0.97|
| L5-S1        | 27/519 (5.2)                  | 0.86|

### Table 3: Relationship between the localization of the discs and migration pathways

| Migration pathways | Subligamentous (n) | Extraligamentous (n) | Total (n) | P |
|--------------------|--------------------|----------------------|-----------|---|
| Caudal             | 524                | 130                  | 654       | 1.319|
| At the level of the disc | 545                | 31                   | 576       | 1.982|
| Cranial            | 28                 | 31                   | 59        | 0.002|
| Total              | 1097               | 192                  | 1289      |  |

**PLL:** Posterior longitudinal ligament

**DISCUSSION**

LDH due to degeneration is classified into four different forms, namely bulging, protrusion, extrusion, or sequestration. Approximately one-third of patients treated for LDH have sequestered discs as reported clearly in large series. The localization and direction of the disc fragment are important factors that determine the surgical technique and affect the results. Only a few studies with a limited number of cases have reported on the direction of disc fragments. In our large series, as few as 4.5% of the disc fragments migrated in the cranial direction.

What factors affect cranial migration of the disc fragment? To our knowledge, no specific studies have addressed this subject in the literature. The structures forming the spinal canal are the most important factors determining the direction of discs due to the force vectors causing disc herniation and passive gravitational pulling. Important anatomical structures, such as the PLL, anterior extradural space, and midline septum, are the main anatomic factors affecting the direction of the disc fragment. PLL is one of the most important structures that provide spinal stability between the posterior surface of the vertebral body and the anterior surface of the dura mater. The PLL has two layers, the superficial and deep layers. The superficial layer is a partly loose structure with longitudinal extension, while the deep layer consists of strong connective tissue with transverse alignment and a segmental structure that is tightly attached to the median part of the annulus fibrosus. The deep and strong layer in this segmental structure is attached to the lower half of the annulus fibrous on the coronal plane and extends caudally. Due to this defined anatomical structure, the median segmental deeper layer beginning from the lower half of the annulus fibrous and extending to the caudal area hinders caudal or cranial migration of the midline loculated discs. In our current study, the fragment that migrated from the intervertebral disc level showed that the tendency toward cranial or caudal migration was much higher when it originated from the lateral direction. In addition, we believe that the corpus pedicle has a barrier effect against the caudal direction of the laterally originated disc herniations. It is known that a strong segmental deep PLL layer with a mean width of 1 cm extends 5 mm to both sides of the midline. Attar et al. reported that the interpedicular distance in the lumbar region was 24 mm. When the axial width of the PLL is considered to be 10 mm, there is approximately 7 mm of extrapoligamentous space on both sides (Figure 5).

It is noteworthy that cranial or caudal migration was more frequent in our study. This result supported the relationship between the migration of the disc fragment to the cranial or caudal direction and the anatomical structure of the PLL. In our study, cranial migration of extrapoligamentous localized disc fragments was significantly more frequent than cranial migration. This difference suggested that the direction of force vectors leading to the disc herniation is important beyond the localization of the disc. It is clear that the static and dynamic morphological structure of the lumbar spine also influences the direction of migration. The pressure generated...
after axial loading on the nondegenerated intervertebral disc is distributed symmetrically over the entire disc integrity. However, if the loader is unilateral, the pressure inside the disc is distributed asymmetrically.\cite{13,14} It is known that biomechanical studies require a very high amount of force to be able to see the annular rupture after axial loadings applied to healthy discs. This suggests the simultaneous presence of multiple accompanying complex forces (torsional, axial rotational, and so forth) to clinically view the annulus rupture. Particularly, rotational and lateral bending movements and rupture of the annulus in the dorsolateral disc area are common.\cite{14} In addition, in a degenerative disc, the axial load is not transferred symmetrically to the entire disc surface but rather is loaded in the dicentric periphery [Figure 6]. Structurally, the dorsolateral region of the intervertebral disc is the area with the least resistance [Figure 7].\cite{15} As a result, we encounter more frequent herniations in the extraligamentous area described. Considering all this information, dynamic studies on the direction of force vectors causing disc herniation will make a significant contribution to the understanding of the cranial migration pathway of the herniated discs.

Today, microdiscectomy is considered to be an effective and reliable method for the treatment of LDHs worldwide.\cite{16} Intraoperative dural tear (1.6%) was detected in only one patient with cranial migration in our series. In those with migration at the level of the disc and in the caudal direction, the dural tear ratio was 4.8%. When the two groups were compared, this difference was statistically significant ($P < 0.05$).

Regardless of the direction in which the disc fragment is migrated, motor weakness was reported preoperatively in 16% of patients treated for LDH.\cite{17} However, in two of our 59 patients with cranial migration, preoperative motor deficits were found at only very low rates of 3.3%. This result was not surprising if the compression effect on the radix and foraminal compartment was considered to be at a minimum level in the cranially migrated disc fragments. In the same study, LDH recurred in 6% of patients regardless of migration pathway.\cite{17} In our current report, no patient with cranial migration had recurrence during the mean follow-up of 38 months. We believe that the rate of recurrence was significantly reduced after surgery for cranial migration due to preservation of the facet joint integrity.\cite{18,19} In addition to all these factors, fragments have been excised via partial hemilaminectomy with specialized instruments, such as micronerve hooks. Although the rate of cranial migration to the corpus height was >75% in 21 patients, Type III surgery was performed in only three. Hence, there was no correlation between the migration rate and width of laminectomy ($P < 0.05$). Considering that there is no linear relationship between the rate of cranial migration of the herniated disc and the amount of laminectomy when planning
the surgery in these cases, minimum resection should be prioritized for the surgery.

CONCLUSION

As a result, extraligamentous disc fragments more frequently migrate in the cranial or caudal direction. The characteristic anatomy of the PLL, the torsional movements, and the loading forces to intervertebral discs are the main causes of the migration pathways of the discs. LDHs with cranial migrations are characteristic and a different surgical technique is necessary for each patient. In addition, complications, such as intraoperative dural tear and postoperative recurrent LDH, are rare in these cases.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Davis CH Jr. Extradural spinal cord and nerve root compression from benign lesions of the lumbar area. In: Youmans JR, editor. Neurological Surgery. Vol. II. Philadelphia: W. B. Saunders; 1973. p. 1165-85.
2. Vucetic N, Astrand P, Güntner P, Svensson O. Diagnosis and prognosis in lumbar disc herniation. Clin Orthop Relat Res 1999;361:116‑22.
3. Fardon DF, Williams AL, Dohring EJ, Murtagh FR, Gabriel Rothman SL, Sze GK, et al. Lumbar disc nomenclature: Version 2.0: Recommendations of the combined task forces of the North American Spine Society, the American Society of Spine Radiology and the American Society of Neuroradiology. Spine J 2014;14:2525‑45.
4. Modic MT. Degenerative disorders of the spine. In: Magnetic Resonance Imaging of the Spine. New York: Year Book Medical; 1989. p. 83-95.
5. Loupasis GA, Stamos K, Katonis PG, Sapkas G, Korres DS, Hartofilakidis G, et al. Seven- to 20-year outcome of lumbar discectomy, Spine (Phila Pa 1976) 1999;24:2313-7.
6. Morgan-Hough CV, Jones PW, Eisenstein SM. Primary and revision lumbar discectomy. A 16-year review from one centre. J Bone Joint Surg Br 2003;85:871‑4.
7. Schellinger D, Manz HJ, Vidic B, Patronas NJ, Deveikis JP, Muraki AS, et al. Disk fragment migration. Radiology 1990;175:831‑6.
8. Ebeling U, Realen HJ. Are there typical localisations of lumbar disc herniations? A prospective study. Acta Neurochir (Wien) 1992;117:143-8.
9. Putz R. Morphology and dynamics of the spinal column. Radiologe 1983;23:145‑50.
10. Chafetz NI, Genant HK, Moon KL, Helms CA, Morris JM. Recognition of lumbar disk herniation with NMR. AJR Am J Roentgenol 1983;141:1153‑6.
11. Fick R. Posterolateral ligament. In: Fick R, editor. Manual of anatomy and joint mechanics. Vol. II. Jena: George Fischer; 1904. p. 80-2.
12. Attar A, Ugur HC, Uz A, Tekdemir I, Egemen N, Genc Y. Lumbar pedicle: Surgical anatomic evaluation and relationships. Eur Spine J 2001;10:10-5.
13. Brown T, Hansen RJ, Yorra AJ. Some mechanical tests on the lumbosacral spine with particular reference to the intervertebral discs; a preliminary report. J Bone Joint Surg Am 1957;39‑A: 1135‑64.
14. Farfan HF, Cossette JW, Robertson GH, Wells RV, Kraus H. The effects of torsion on the lumbar intervertebral joints: The role of torsion in the production of disc degeneration. J Bone Joint Surg Am 1970;52:468‑97.
15. Kazarian LE. Creep characteristics of the human spinal column. Orthop Clin North Am 1975;6:3‑18.
16. Wang XS, Sun RF, Ji Q, Zhao B, Niu XM, Wang R, et al. A meta-analysis of interlaminar minimally invasive discectomy compared to conventional microdiscectomy for lumbar disk herniation. Clin Neurol Neurosurg 2014;127:149‑57.
17. Albayrak S, Ozturk S, Durdag E, Ayden O. Surgical management of recurrent disc herniations with microdiscectomy and long-term results on life quality: Detailed analysis of 70 cases. J Neurosci Rural Pract 2016;7:87‑90.
18. Parker SL, Xu R, McGirt MJ, Witham TF, Long DM, Bydon A. Long-term back pain after a single-level discectomy for radiculopathy: Incidence and health care cost analysis. J Neurosurg Spine 2010;12:178‑82.
19. Trummer M, Eustacchio S, Barth M, Klassen PD, Stein S. Protecting facet joints post-lumbar discectomy: Barricaid annular closure device reduces risk of facet degeneration. Clin Neurol Neurosurg 2013;115:1440‑5.