Characteristics of relief and residual low back pain after discectomy in patients with lumbar disc herniation: analysis using a detailed visual analogue scale

Hiroshi Takahashi (hirochann@syd.odn.ne.jp)
University of Tsukuba  https://orcid.org/0000-0002-3497-4802

Yasuchika Aoki
Eastern Chiba Medical Center

Masahiro Inoue
Eastern Chiba Medical Center

Junya Saito
Toho University Sakura Medical Center

Arata Nakajima
Toho University Sakura Medical Center

Masato Sonobe
Toho University Sakura Medical Center

Yorikazu Akatsu
Toho University Sakura Medical Center

Keita Koyama
Toho University Sakura Medical Center

Yasuhiro Shiga
Chiba University Graduate School of Medicine

Kazuhide Inage
Chiba University Graduate School of Medicine

Yawara Eguchi
Chiba University Graduate School of Medicine

Sumihisa Orita
Chiba University Graduate School of Medicine

Satoshi Maki
Chiba University Graduate School of Medicine

Takeo Furuya
Chiba University Graduate School of Medicine

Tsutomu Akazawa
St. Marianna University School of Medicine
Research article

**Keywords**: lumbar disc herniation, residual low back pain, visual analog scale, radicular low back pain

**DOI**: https://doi.org/10.21203/rs.3.rs-50029/v2

**License**: ☑️ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)
Abstract

**Background:** Several authors have reported favorable results in low back pain (LBP) for patients with lumbar disc herniation (LDH) treated with discectomy. However, detailed changes over time in the characteristics and location of LBP before and after discectomy for LDH remain unclear. To clarify these points, we conducted an observational study to determine the detailed characteristics and location of LBP before and after discectomy for LDH, using a detailed visual analog scale (VAS) bilaterally.

**Methods:** We included 65 patients with LDH treated by discectomy in this study. A detailed VAS for LBP was administered with the patient under 3 different conditions: in motion, standing, and sitting. Bilateral VAS was also administered (affected versus opposite side) for LBP, lower extremity pain (LEP), and lower extremity numbness (LEN). The Oswestry Disability Index (ODI) was used to quantify clinical status. Changes over time in these VAS and ODI were investigated. Pfirrmann grading and Modic change as seen by magnetic resonance imaging (MRI) were reviewed before and 1 year after discectomy to determine disc and endplate condition.

**Results:** Before surgery, LBP on the affected side while the patients were in motion was significantly higher than LBP while they were sitting. This increased LBP on the affected side in motion was improved significantly after discectomy. By contrast, the residual LBP while sitting at 1 year after surgery was significantly higher than the LBP while they were in motion or standing. At 1 year following discectomy, residual LBP while sitting was significantly greater in cases showing changes in Pfirrmann grade or Modic type.

**Conclusions:** Improvement of LBP on the affected side while the patient is in motion suggests that radicular LBP is improved following discectomy by nerve root decompression. Furthermore, that residual LBP is found while the patient is sitting is reflective of the load and pressure put on the disc and endplate.

**Background**

Lumbar disc herniation (LDH) is one of the most common causes of low back pain (LBP) and sciatica. Surgical treatment is well known to be beneficial for patients with LDH who fail to respond to conservative care. Favorable results for LBP, lower extremity pain (LEP), and lower extremity numbness (LEN) in patients with LDH treated with discectomy have been demonstrated [1, 2, 3, 4]. In most of those studies, only a conventional visual analog scale (VAS) and the Oswestry disability index (ODI) were used to determine LBP. Those studies were unable to determine detailed changes in LBP and the characteristics of relief and residual LBP. By contrast, recent reports have clarified the characteristics of LBP using a detailed VAS for some lumbar degenerative disorders, including spondylolysis and lumbar spinal stenosis (LSS) [5, 6, 7]. Nevertheless, there are no reports of the detailed changes and location of LBP before and after discectomy for LDH. Thus, we conducted an observational study to clarify the detailed characteristics and location of LBP, LEP, and LEN before and after discectomy for LDH using detailed VAS bilaterally.
Methods

Patient selection

The present study was approved by the ethics committee of Toho University Sakura Medical Center (No. 2012071). Informed consent was obtained from all patients. In the present study, we enrolled a total of 114 patients under the age of 75 who were treated with discectomy for LDH from April 2010 to March 2018. LDH was diagnosed by 4 orthopedic spine surgeons (HT, YaA, MI, JS) based on neurological findings, the presence of persistent and unremitting LBP for more than 3 months, X-ray images, and magnetic resonance imaging (MRI). All the patients were treated conservatively. Those who were not improved by sufficient conservative treatment and wished to undergo surgical treatment were included in this study. Patients with LSS or degenerative spondylolisthesis (DS) comorbidities were excluded. Patients who were diagnosed with a lateral herniation treated with fusion surgery were excluded, as were those with thoracic myelopathy and hip osteoarthritis. Patients with recurrent herniation were excluded, and unfortunately so were those who had a recurrence of herniation and underwent revision surgery within 1 year of their primary surgery. The categories of patients excluded from the study due to these complications, are broken down as follows: 5 patients with LSS or DS, 7 patients with lateral herniation, 1 patient with thoracic myelopathy, 1 patient with hip osteoarthritis, and 7 patients with recurrent herniation. Unfortunately, 5 patients (4.3%) had a rapid (less than one -year post op) recurrence of herniation. In addition, 5 patients were excluded because of a lack of data and 18 patients because of a loss to follow-up. Ultimately, data from 65 patients were included in the present study.

Discectomy procedure

All the surgical procedures were performed under an operating microscope as described in detail elsewhere [8]. We performed 59 of 65 surgeries using a hemi approach. In the first 31 patients, the surgeries were performed using the conventional microdiscectomy. In the 28 patients treated since 2015, the surgeries were performed using a tubular retractor (METRx MD system, Medtronic, US) to minimize damage to the paraspinal muscles on the approached side. Six of the patients experienced bilateral symptoms with a central herniation. Therefore, we performed bilateral fenestration and bilateral extirpation of herniation.

Clinical outcome

In this study, buttock pain was included in LEP and, therefore, the definition of LBP in this study does not include buttock pain. Based on past reports, a detailed VAS (100 mm) score for LBP was obtained under 3 conditions: while the patient was in motion, standing, and sitting (Fig. 1A) [5, 6]. In addition, the location (left versus right side) of LBP, LEP, and LEN were determined and analysis performed of the affected (approached) and opposite side (Fig. 1B) [6]. At the time of the outpatient examination, we carefully explained how to complete the questionnaire to each patient, especially for the LBP in the 3 different situations (in motion, while standing, and while sitting) and the point that LBP did not include buttock pain. In the patients with bilateral symptoms who underwent bilateral laminectomy and herniation
extirpation, we established the affected side as the one that was more symptomatic and more extensively herniated on MRI. The ODI was also used to assess clinical improvement and included activities of daily living. All VAS and ODI values were determined before surgery, at 3 months, at 6 months, and at 1-year of follow-up. We investigated the relationship between the VAS scores and surgical level as well as in the following 3 surgical groups: conventional discectomy with hemi-laminectomy (C), discectomy using a tubular retractor (T), and discectomy with bilateral laminectomy (B).

**Imaging**

We analyzed MRI before surgery and at the 1-year follow-up, except for 3 patients who were unable to undergo MRI because of a pacemaker insertion (1 patient) or claustrophobia (2 patients). In total, we analyzed MRI from 62 patients. We determined disc degeneration using the Pfirrmann grading [9]. Vertebral endplate changes were determined using Modic type [10]. All the MRI analyses were conducted independently by 3 examiners (YE, KI, and KoM) who were blinded to clinical data from the patients. The patients were divided into 2 groups: C group and N group according to their changes of Pfirrmann grade or Modic type before and after discectomy. Differences between the 2 groups were determined.

**Statistical analyses**

Results are presented as the mean ± standard deviation. A paired $t$ test was used to compare each detailed VAS score before and after surgery. A one-factor ANOVA was used to compare the relationship between VAS scores and the 3 different surgical levels and procedures. A repeated measures ANOVA followed by a post hoc Turkey–Kramer test was used to determine changes over time for each VAS and the ODI. A Student $t$ test was used to compare changes in Pfirrmann grade or Modic type with residual LBP, as measured by VAS. We considered $p < 0.05$ significant in the tests of statistical inference. All statistical analyses were performed using JMP software (version 14.2.0, SAS Institute, Cary, NC, USA).

**Results**

**Patient characteristics**

Table 1 shows the characteristics of the 65 patients whose data was included in the present study. There was no significant difference between sex and the affected side. Herniations at L4-5 and L5-S were more frequent than at L3-4 in this series. There were no cases of L1-2 or L2-3 herniation included in this study. Disc degeneration by Pfirrmann grading showed that grade 2 was most frequent and there were no cases of grade 1. Fourteen patients showed endplate changes as determined by Modic type. There were no cases of surgical site infection in this series, nor were there other critical complications such as thromboembolic events or nerve root injuries.

**Clinical outcomes (VAS and ODI)**

The time course changes of detailed LBP VAS scores are shown in Table 2. Before surgery, LBP while the patient was in motion was significantly higher than LBP while they were sitting (paired $t$ test, $p < 0.05$).
The increased LBP found while they were in motion as well as the LBP while they were standing and sitting was significantly improved following discectomy (repeated majors ANOVA, \( p < 0.05 \)). By contrast, at 1 year after surgery, the residual LBP while they were sitting was significantly higher than the LBP while they were in motion or standing (paired \( t \) test, \( p < 0.05 \)). The time course changes of bilateral LBP, LEP, and LEN VAS scores were shown in Table 3. LBP on the affected side was significantly higher than that on the opposite side (paired \( t \) test, \( p < 0.05 \)). The LBP on the affected side was improved significantly following surgery, and LBP relief was maintained on both sides until the 1 year follow-up. LEP and LEN on the affected side were also significantly greater than before surgery (paired \( t \) -test, \( p < 0.01 \)). Significant improvements of LEP and LEN on the affected side were shown and the relief was maintained on both sides until the 1 year follow-up (repeated measures ANOVA, \( p < 0.01 \)), although mild LEP and LEN remained on the affected side. ODI also showed significant improvements following discectomy (Table 4).

Taking the results of the detailed LBP VAS scores into account, we investigated the temporal changes in LBP VAS scores while the patient was in motion and while they were sitting. The time course of changes of the detailed LBP VAS and surgical level are shown in Figure 2. There was no significant difference in LBP before surgery at the various surgical levels. However, the residual LBP VAS score while the patient was in motion and while they were sitting was significantly increased at the L3-4 level at 1 year after surgery (one factor ANOVA, \( p < 0.01 \)).

Time course changes in detailed LBP VAS scores and surgical procedures (C, T, and B groups) were shown in Figure 3. LBP while the patients were in motion was significantly higher before surgery in those of group T (one factor ANOVA, \( p < 0.05 \)), and therefore the residual LBP at 3 months after surgery was also higher in those in group T. However, at 1 year after discectomy, the residual LBP became almost equal for all 3 surgical procedures.

**Correlation between MRI findings and VAS**

The time course of changes in Pfirrmann grade and Modic type are shown in Table 5. Overall, significant changes in both Pfirrmann grade and Modic type were observed (Chi-squared test, \( p < 0.05 \)). Seventeen patients had changes in Pfirrmann grade following discectomy. We divided them into 2 groups: Pfirrmann grade changing (PC group) and not changing (PN group). After discectomy, Modic type changed in 12 patients, and we also divided them into 2 groups: Modic type changing (MC group) and not changing (MN group).

Considering that residual LBP while the patient was sitting was increased at 1 year after discectomy, we investigated the relationship between the Pfirrmann grade, Modic type, and LBP VAS score while the patients were sitting at 1 year after discectomy. LBP VAS scores while they were sitting at 1 year after discectomy were 31.5 ± 21.1 for those in the PC group and 12.9 ± 20.7 for those in the PN group; notably, they were significantly higher in those in the PC group (\( p < 0.05 \), Fig 4A). In addition, LBP VAS scores while they were sitting at 1 year after discectomy were 30.8 ± 25.7 for those in the MC group and 14.9 ±
20.5 for those in the MN group, showing the scores were significantly higher in those in the MC group ($p < 0.05$, Fig 4B).

**Discussion**

To our knowledge, this study is the first to determine the characteristics and location of LBP using a detailed VAS we developed in patients with LDH treated with discectomy. According to a previous study that analyzed detailed and bilateral VAS scores for LSS patients, LBP in patients with LSS before surgery were significantly greater while the patient was standing, but pain was reduced by decompression surgery, with LBP improving equally on the affected and opposite sides [6]. The first noteworthy point of the present study is that LBP while the patients were in motion was significantly greater in those with LDH before surgery, and the LBP while they were in motion on the affected side was reduced by discectomy. This pattern of LBP relief suggests that radicular LBP is improved by nerve root decompression surgery, as indicated in previous reports [1, 6]. However, despite this similarity regarding nerve root decompression, the greater LBP that occurred in patients with LDH while they were in motion was distinct from the increased LBP found while patients with LSS were standing. For this reason, we speculate that nerve root compression in patients with LDH usually occurs with a more acute onset than that in patients with LSS. In addition, this difference in LBP characteristics may be influenced by the degree of disc and endplate degeneration in patients with LDH compared with those with LSS because patients with LDH tend to be younger than those with LSS.

Another noteworthy point gleaned from our findings is that residual LBP was most pronounced while the patient was sitting. A recent report indicated that higher intradiscal pressure while sitting may result in LBP in the presence of lumbar degenerative disc diseases [11]. Pathological mechanisms of discogenic low back pain included sensory nerve ingrowth into the disc, upregulation of neurotrophic factors like nerve growth factor and inflammatory cytokines, and mechanical stress [12, 13]. Our findings of residual LBP while the patients were sitting and changes in Pfirrmann grade, when taken in combination, suggests that the load and pressure on the disc cause residual LBP while the patient is sitting. Alternatively, it is also well known that Modic changes influence LBP [14]. Ohtori et al. reported favorable surgical outcomes for LDH complicated with Modic type I [15]. Although LEP improvement was obtained in patients with Modic change in our study, the residual LBP in the MC group leads us to believe that changes in load and inflammation at the endplate may also cause residual LBP while the patient is sitting.

Recent reports indicated that performing a minimally invasive discectomy using a tubular retractor under a microscope or endoscope is feasible for the treatment of LDH [16, 17]. In the present study, we compared these 3 surgical procedures, including conventional discectomy. Residual LBP at 3 months after surgery was greater in patients in group T because the baseline of LBP before surgery was significantly greater in those in this group. However, the residual LBP at 1 year follow up was equal following all 3 surgical procedures. This, along with previous reports, suggests that surgical invasion of the paraspinal muscles does not influence residual LBP [6, 16]. In addition, in the analysis of the residual
LBP at 1 year follow up except for cases of bilateral laminectomy (group B), we found similarly that LBP
while the patient is sitting was significantly higher than the LBP found when the patient was in motion or
standing. Furthermore, recent reports indicated that the surgical procedure (open discectomy versus
micro discectomy) did not influence the surgical outcome for the residual pain [18, 19]. Although
including the 3 different surgical methods may present the bias in the present study, we speculate that
the type of surgical procedures did not much influence the result for the residual LBP.

While no reports describing the relationship between surgical levels and residual LBP were found, in the
present study, residual LBP was significantly greater in patients with herniations at L3-4. It is difficult to
explain this phenomenon. However, we speculate that this may have been because patients with L3-4
herniations were highly complicated and also had L4-5 or L5-S disc degenerations. Further investigation
with a larger sample size is needed to understand this residual LBP.

The present study has several limitations. First, the present study is observational, and we did not
evaluate detailed and bilateral LBP VAS scores of patients who underwent conservative treatment alone.
In our study some of the patients underwent conservative treatment at another hospital, and they wished
to undergo surgical treatment as soon as possible, leaving no time to evaluate further conservative
treatment. Further prospective investigation will be needed to clarify this point. Second, in the present
study, we investigated only ODI as a patient-based outcome and did not investigate other patient-based
outcomes such as SF-36, EQ-5D, and JOA BPEQ. This is a major limitation of the present study. Although
such patient-based outcomes are also important, the main purpose of this study was to determine the
degree of detailed LBP under various conditions (while the patient was in motion, sitting, and standing).
However, patient-based outcomes could not determine the LBP in various conditions and may include
postsurgical psychogenic factors. To simplify the result, we only investigated VAS scores and ODI. Third,
the present study excluded patients complicated with dynamic instability or patients with lateral
herniations who underwent fusion surgery because we wanted to avoid LBP caused by instability of discs
and facet joints [20]. Furthermore, the present study also excluded patients who, unfortunately, had a
recurrence of herniation in the short term (less than a year postoperatively) because we wanted to
determine residual LBP in the absence of herniation recurrence. If those cases had been included, the
results would have been confounded because they had high VAS scores under all 3 conditions. Fourth,
the present study did not evaluate sagittal alignment. Sagittal imbalance such as pelvic incidence and
lumbar lordosis mismatch may contribute to postoperative LBP [21]. Using detailed VAS scores, Aoki et
al. indicated that sagittal imbalance after a short segment fusion surgery resulted in residual LBP while
the patient was standing [22]. Considering our finding that residual LBP while the patient was sitting was
present at 1 year after discectomy, we speculate that residual LBP is less affected by sagittal alignment.
Finally, the follow up after discectomy was incomplete. When patients undergo discectomy and have
significant pain relief, they sometimes drop out of care at the outpatient clinic. In the present study, 18 of
114 (15.7%) patient participants dropped out. Generally, 2 years of follow-up is recommended for this
type of study. However, in the present study, we were compelled to set the follow-up period to 1 year
because of a decreasing follow-up rate. Further investigation, such as a prospective cohort study that
follows all the cases fully will be needed to resolve this follow-up issue.
Conclusions

In patients with LDH, LBP on the affected side while they are in motion was significantly greater before surgery and was reduced following discectomy. This LBP relief suggests a radicular nature to the LBP that is improved by nerve root decompression surgery. The residual LBP at 1 year after discectomy was most dominant while they were sitting. This, in combination with our findings regarding the relationship between residual LBP and changes in Pfirrmann grade and Modic type, suggests that the load and pressure on the disc and endplate play a causal role in residual LBP while the patient is sitting.

Abbreviations

LDH: Lumbar disc herniation, LBP: low back pain, LEP: lower extremity pain, LEN: lower extremity numbness, VAS: Visual analog scale, ODI: Oswestry disability index, LSS: lumbar spinal stenosis, MRI: magnetic resonance imaging, DS: degenerative spondylolisthesis,

Declarations

Ethic approval and consent to participate

This study was approved by the ethical committee of Toho University Sakura Medical Center (No. 2012071). Verbal informed consent was obtained from all participants because the investigation of VAS and ODI are noninvasive and beneficial for all the patients to know their real condition. The ethical committee approved this procedure.

Consent to publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research did not receive any specific grant funding agencies in the public, commercial, or not-for-profit sectors.

Authors’ Contributions
HT, YaA, YaS, KI, SuO, YE, SM, TaF, TsuA, TeA, ToF, MasK, MY, and SeO conceived of the study. HT drafted
the manuscript. KeM, YoS, FE, and MamK performed the literature search. YE, KI, and KoM evaluated MRI.
YaA, MI, JS, AN, MS, YoA, KK, and KN contributed to clinical management of the case. YaA, SuO, TsuA,
MasY and SeO revised the manuscript critically and approved the modified text. All authors have read
and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Toyone T, Tanaka T, Kato D, Kaneyama R: Low-back pain following surgery for lumbar disc
    herniation. A prospective study. The Journal of bone and joint surgery American volume 2004, 86-
    a(5):893-896.
2. Kikuchi S: The Recent Trend in Diagnosis and Treatment of Chronic Low Back Pain. Spine Surgery
    and Related Research 2017, 1(1):1-6.
3. Oba H, Takahashi J, Tsutsumimoto T, Ikekami S, Ohta H, Yui M, Kosaku H, Kamanaka T, Misawa H,
    Kato H: Predictors of improvement in low back pain after lumbar decompression surgery:
    Prospective study of 140 patients. Journal of orthopaedic science : official journal of the Japanese
    Orthopaedic Association 2017, 22(4):641-646.
4. Parker SL, Mendenhall SK, Godil SS, Sivasubramanian P, Cahill K, Ziewacz J, McGirt MJ: Incidence of
    Low Back Pain After Lumbar Discectomy for Herniated Disc and Its Effect on Patient-reported
    Outcomes. Clinical orthopaedics and related research 2015, 473(6):1988-1999.
5. Aoki Y, Sugiura S, Nakagawa K, Nakajima A, Takahashi H, Ohtori S, Takahashi K, Nishikawa S:
    Evaluation of nonspecific low back pain using a new detailed visual analogue scale for patients in
    motion, standing, and sitting: characterizing nonspecific low back pain in elderly patients. Pain Res
    Treat 2012, 2012:680496.
6. Takahashi H, Aoki Y, Saito J, Nakajima A, Sonobe M, Akatsu Y, Inoue M, Taniguchi S, Yamada M,
    Koyama K et al: Unilateral laminectomy for bilateral decompression improves low back pain while
    standing equally on both sides in patients with lumbar canal stenosis: analysis using a detailed
    visual analogue scale. BMC musculoskeletal disorders 2019, 20(1):100.
7. Sugiura S, Aoki Y, Toyooka T, Shiga T, Otsuki K, Aikawa E, Oyama T, Kitoh K, Chikako S, Takata Y et
    al: Characteristics of low back pain in adolescent patients with early-stage spondylolysis evaluated
    using a detailed visual analogue scale. Spine 2015, 40(1):E29-34.
8. Blamoutier A: Surgical discectomy for lumbar disc herniation: surgical techniques. Orthopaedics &
    traumatology, surgery & research : OTSR 2013, 99(1 Suppl):S187-196.
9. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N: Magnetic resonance classification of lumbar
    intervertebral disc degeneration. Spine 2001, 26(17):1873-1878.
10. Modic MT, Steinberg PM, Ross JS, Masaryk TJ, Carter JR: Degenerative disk disease: assessment of changes in vertebral body marrow with MR imaging. Radiology 1988, 166(1 Pt 1):193-199.

11. Tonosu J, Inanami H, Oka H, Katsuhira J, Takano Y, Koga H, Yuzawa Y, Shiboi R, Oshima Y, Baba S et al: Diagnosing Discogenic Low Back Pain Associated with Degenerative Disc Disease Using a Medical Interview. PloS one 2016, 11(11):e0166031.

12. Ohtori S, Miyagi M, Inoue G: Sensory nerve ingrowth, cytokines, and instability of discogenic low back pain: A review. Spine Surgery and Related Research 2018, 2(1):11-17.

13. Aoki Y, Nakajima A, Ohtori S, Takahashi H, Watanabe F, Sonobe M, Terajima F, Saito M, Takahashi K, Toyone T et al: Increase of nerve growth factor levels in the human herniated intervertebral disc: can annular rupture trigger discogenic back pain? Arthritis research & therapy 2014, 16(4):R159.

14. Ohtori S, Inoue G, Ito T, Koshi T, Ozawa T, Doya H, Saito T, Moriya H, Takahashi K: Tumor necrosis factor-immunoreactive cells and PGP 9.5-immunoreactive nerve fibers in vertebral endplates of patients with discogenic low back Pain and Modic Type 1 or Type 2 changes on MRI. Spine 2006, 31(9):1026-1031.

15. Ohtori S, Yamashita M, Yamauchi K, Inoue G, Koshi T, Suzuki M, Orita S, Eguchi Y, Ochiai N, Kishida S et al: Low back pain after lumbar discectomy in patients showing endplate modic type 1 change. Spine 2010, 35(13):E596-600.

16. Overdevest GM, Peul WC, Brand R, Koes BW, Bartels RH, Tan WF, Arts MP: Tubular discectomy versus conventional microdiscectomy for the treatment of lumbar disc herniation: long-term results of a randomised controlled trial. Journal of neurology, neurosurgery, and psychiatry 2017, 88(12):1008-1016.

17. Kim M, Lee S, Kim HS, Park S, Shim SY, Lim DJ: A Comparison of Percutaneous Endoscopic Lumbar Discectomy and Open Lumbar Microdiscectomy for Lumbar Disc Herniation in the Korean: A Meta-Analysis. BioMed research international 2018, 2018:9073460.

18. Kamper SJ, Ostelo RW, Rubinstein SM, Nellensteijn JM, Peul WC, Arts MP, van Tulder MW: Minimally invasive surgery for lumbar disc herniation: a systematic review and meta-analysis. Eur Spine J 2014, 23(5):1021-1043.

19. Li X, Chang H, Meng X: Tubular microscopes discectomy versus conventional microdiscectomy for treating lumbar disk herniation: Systematic review and meta-analysis. Medicine 2018, 97(5):e9807.

20. Johnsson KE, Willner S, Johnsson K: Postoperative instability after decompression for lumbar spinal stenosis. Spine 1986, 11(2):107-110.

21. Schwab F, Patel A, Ungar B, Farcy JP, Lafage V: Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. Spine 2010, 35(25):2224-2231.

22. Aoki Y, Nakajima A, Takahashi H, Sonobe M, Terajima F, Saito M, Takahashi K, Ohtori S, Watanabe A, Nakajima T et al: Influence of pelvic incidence-lumbar lordosis mismatch on surgical outcomes of short-segment transforaminal lumbar interbody fusion. BMC musculoskeletal disorders 2015, 16:213.
Tables

Due to technical limitations, the tables are only available as a download in the supplemental files section.