International Journal of Biology and Life Sciences
ISSN: 2957-9511 | Vol. 6, No. 1, 2024

Research Progress on the Effect of Unilateral Biportal Endoscopic on Lumbar Stability in the Treatment of Lumbar Disc Herniation

Keyi Long [1], Jiayun Zhong [2, *], Songlin Li [1]

[1] Graduate School of Youjiang Medical University for Nationalities, Baise, Guangxi Zhuang Autonomous Region, China
[2] The Red Cross Hospital of Yulin City, Yulin, Guangxi Zhuang Autonomous Region, China

*** Corresponding author:** Jiayun Zhong

Abstract: Lumbar disc herniation (LDH) is a common disease in spine surgery, characterized by typical symptoms of low back and leg pain, which can lead to sensory disturbances in the lower limbs, muscle weakness, and in severe cases, urinary and fecal dysfunction. For patients with poor response to conservative treatment, surgical treatment should be considered. Traditional open surgery causes large trauma and varying degrees of damage to the paravertebral muscles, facet joints, and surrounding ligaments, affecting the stability of the spine. With the development of the concept of minimally invasive surgery and the improvement of endoscopic surgical techniques, minimally invasive spine surgery has been widely used in the treatment of degenerative lumbar diseases. Unilateral biportal endoscopic (UBE) has been used in the treatment of various spinal disorders, causing minimal damage to the different structures. This article provides a review of the progress of UBE treatment on the impact of lumbar stability.

Keywords: Lumbar Disc Herniation; Unilateral Biportal Endoscopic; Minimally Invasive Spine Surgery; Spinal Stability.

1. Introduction

Lumbar disc herniation is a common clinical cause of back and leg pain, accounting for approximately 87.6% of the musculoskeletal disorders leading to back pain[1, 2].Currently, most scholars believe that this is due to the compression of the dura sac and adjacent nerve roots by the protruding nucleus pulposus tissue, as well as the stimulation caused by inflammatory mediators released by the protruding nucleus pulposus tissue[3-5].Surgery is one of the effective methods for treating lumbar disc herniation.

In the past, open surgery mainly involved decompressing the dural sac and nerve roots through total or subtotal laminectomy as well as extensive separation of paravertebral muscles and ligaments[6].This may lead to fat degeneration, atrophy, paravertebral muscle weakness, and damage to supporting tissues such as small joints and ligaments[7, 8]. Over dissection of paravertebral muscles, especially the multifidus muscle, may lead to back pain, muscle atrophy, and inevitable iatrogenic instability caused by extensive decompression, including laminectomy[9].The number of lumbar fusion surgeries is also increasing, and adjacent segmental degeneration may occur after lumbar fusion, leading to an increased probability of secondary surgeries[10].A long-term follow-up study on patients with LDH showed that 3%-36% of patients still experience persistent back pain after surgery[11, 12].Possible factors leading to this issue include the disruption of ligaments, paraspinal muscles, and facet joints caused by open surgery.

Today, the development of minimally invasive concepts and improvements in surgical techniques, coupled with the extraordinary demand of patients for minimally invasive surgery, have driven the rapid development of endoscopic spinal surgery.[13]Minimally invasive spinal surgery is widely used in the treatment of degenerative diseases of the lumbar spine. It can maximize the preservation of the structural integrity of the spine, and patients tend to recover faster after the surgery[14, 15].Compared with traditional open or microscopic discectomy, endoscopic discectomy has many advantages such as small skin incision, less bleeding, short hospital stay, less tissue damage, and fast recovery, and has become a popular surgical option for treating lumbar disc herniation[16].Currently, the mainstream spinal endoscopic nucleus pulposus removal procedures mainly include percutaneous endoscopic lumbar discectomy (PELD) with percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID), as well as unilateral biportal endoscopic discectomy (UBED)[17].

UBE is a type of percutaneous total intracavitary endoscopy technology first reported by Daniel in 1996[18].UBE is a percutaneous endoscopic technology that is not limited by a working tube or working channel. It is performed through two small surgical incisions on the right or left side of the spinous process. One channel is used for the endoscope and the inflow of normal saline, and the other channel is used for the passage of instruments and the outflow of normal saline. In recent years, with the continuous improvement of the dual-channel theory, the continuous innovation of operating instruments, and the deepening of the concept of minimally invasive surgery, UBE has been widely used in the treatment of different types of lumbar disc herniation and recurrent lumbar disc herniation, vertebral slippage, lumbar spinal stenosis. It can not only perform simple decompression but also vertebral fusion, and even be used to treat different cervical and thoracic spine diseases[19].This article provides an overview of whether the anatomy of the lumbar vertebrae affected by Unilateral biportal endoscopic treatment for lumbar disc herniation affects the stability of the lumbar vertebrae.

2. Physiological Anatomy

A thorough understanding and mastery of the anatomical structure and biomechanical characteristics of each part of the spine, as well as their differences, is crucial for accurately understanding the pathological processes of spinal diseases and injuries and selecting appropriate treatment plans. The stability of the lumbar spine in the physiological state is maintained by ligaments, facet joints, intervertebral discs, and the surrounding muscles of the spine. The stable structure of the spine is divided into two parts: intrinsic stable structures that make up various structures of the spine itself, and extrinsic stable structures mainly consisting of the muscular system[20].The internal stable structure of the spine is divided into anterior and posterior structures. The anterior stable structure includes the vertebral body, intervertebral disc, and anterior and posterior longitudinal ligaments. The posterior stable structure is composed of facet joints, ligamentum flavum, lamina, spinous processes, supraspinous ligament, and interspinous ligament. The intervertebral disc is located in the anterior part of the lumbar vertebrae, and the facet joints are located on the sides of the lumbar vertebrae, together forming the trijoint complex, which jointly maintains the stability of the lumbar vertebrae, playing a role in transmitting loads, guiding, and limiting lumbar spine movement[21],It ensures the normal transmission of various shear and compressive forces, allowing the human body to perform a variety of movements. The stability of the lumbar spine is greatly important for the trijoint complex. Degeneration or asymmetry of the lumbar facet joints has a significant impact on the function of the trijoint complex[22].

In 1952, Harris first proposed the concept of lumbar segmental instability. However, there is currently widespread controversy in clinical practice regarding the definition, understanding, and diagnostic criteria for lumbar instability, and there is no unified standard yet[23].At present, lumbar instability can be defined as abnormal displacement occurring within the motion segment when normal physiological loads are applied[24].Factors affecting the stability of the lumbar spine are diverse and can be divided into the following aspects: (1) Anatomical factors: Degenerative changes in the intervertebral disc, spinal stenosis, facet joint wear, ligament laxity, or rupture may lead to instability of the lumbar spine; (2) Biomechanical factors: Factors such as excessive load, poor posture, or imbalance can lead to a decrease in the biomechanical performance of the lumbar spine, thereby causing instability; (3) Muscle factors: Imbalance in the strength of the muscles in the lumbar region, such as weakness or spasms in the lumbar and abdominal muscles, can lead to lumbar instability; (4) Fracture or pathological factors: Factors such as lumbar vertebral fracture, tumor erosion and damage, surgery, or inflammation caused by infection can all cause damage to the structure of the lumbar spine. Posterior lumbar surgery can cause a certain degree of damage to the paraspinal muscles, facet joints, intervertebral discs, and the surrounding ligaments.

3. Changes in the Structures Around the Spine after Injury

3.1. Facet Joint

The zygapophyseal joints (including synovial joints and joint capsules) are considered an important anatomical region and stabilizer of the spine, as they play a key role in load transmission, stabilize motion segments during flexion and extension as posterior weight-bearing components, while also limiting axial rotation. Along with the intervertebral disc, the zygapophyseal joints transmit loads and guide and constrain spinal motion. However, changes in the tissues within the zygapophyseal joints due to injury, degenerative changes, or spinal surgery may lead to joint dysfunction, thereby disrupting the stability of the zygapophyseal joints[25].Biomechanical tests indicate that more than 50% of facet joint damage can lead to segmental instability[26].Some studies suggest[27]that partial resection of bilateral facet joints has little impact on the stability of the lumbar spine, while complete resection of bilateral facet joints leads to an increase in the range of motion in extension and rotation of the segment. Some researchers[28]used finite element method to simulate graded resection of the facet joint in a single segment, and found that when the bilateral facet joint resection reached 1/3, the range of motion in flexion increased by 18%, extension increased by 27%, and lateral bending increased by 45% compared to the preoperative intact model. Additionally, as the range of facet joint resection increased, the range of motion also increased. When the bilateral facet joint resection reached 1/3, it may cause instability in the degenerative lumbar spine segment. Typical degenerative changes that occur after injury to the small joints and surrounding ligaments include cartilage degeneration, followed by narrowing of the joint space and subchondral bone sclerosis[29],At this point, excessive posterior column movement at the small joints (due to excessive joint activity or ligament laxity leading to instability) can exert excessive pressure on the intervertebral disc, potentially leading to disc protrusion or degenerative changes. Researchers [30] simulated total vertebral plate resection, hemi-vertebral plate resection, and laminectomy decompression surgery based on a finite element model of the lumbar spine. They compared the range of motion of the decompressed segment and the corresponding stress changes in the intervertebral disc. After the facet joint resection, the ability of the lumbar spine segment to limit rotational motion significantly decreased, and accelerated damage and degeneration of the intervertebral disc may occur. The posterior ligamentous complex (PLC) is also crucial for maintaining spinal stability, and consists of the supraspinous ligament, interspinous ligament, ligamentum flavum, and facet joint capsule ligament. The function of the posterior ligamentous complex (PLC) is to limit excessive motion and resist bending and compressive forces. The following two studies evaluated the effects of various ligament dysfunctions in the PLC. Excision of the facet joint capsule ligament in the lower lumbar spine leads to a significant increase in pressure within the previously healthy intervertebral disc[31],while cutting these ligaments in the upper lumbar spine leads to increased lateral bending motion[32].Therefore, when the posterior ligamentous complex (PLC) is injured, it can lead to an increase in shearing force (lateral movement), thereby increasing the possibility of instability, as well as subsequent degenerative changes in the facet joints and lumbar intervertebral discs.

3.2. Paraspinal Muscles

The paraspinal muscle (PSM) is the fundamental determinant of the stability and function of the lumbar spine structure[33].PSM encompasses the muscles surrounding the spine, such as the psoas major, multifidus, and erector spinae muscles. Maintaining the proper functionality of the PSM is critical for spinal structure integrity. Specifically, the lumbar multifidus muscle (LMM) constitutes the largest posterior muscle group in the lumbosacral region, playing a significant role in local stability. Comprising multiple muscle bundles and occupying the grooves along the spinous processes, it is located deep within the back and has the most substantial attachment area among the paraspinal muscles. The lumbar multifidus muscle is enveloped within the muscle sheath formed by the superficial and middle layers of the thoracolumbar fascia. The longest muscle, spinous processes, and vertebral lamina are located on the lateral, medial, and ventral sides of the multifidus muscle[34].The multifidus muscle (LMM) specifically functions to maintain the stability of the spinal segments, preserve the physiological lordosis of the lumbar spine, control the movement of the facet joints, and regulate the distribution of intervertebral loads and pressure. Kuan et al[35]compared a trunk musculoskeletal model based on 250 healthy adults with and without the multifidus muscle. The model without the multifidus muscle showed an increased estimate of compressive loads in the flexed trunk position compared to the model with the multifidus muscle. In some cases, the absence of the multifidus muscle may exacerbate the pressure on the lumbar spine, with values approximately double the average. During the exposure process of lumbar spine posterior surgery, the paravertebral muscles inevitably undergo detachment and injury[36],leading to muscle degeneration characterized by muscle fiber atrophy, fibrous bundle and fat infiltration. When these pathological changes occur, they alter the original biomechanical relationships and increase the load on the intervertebral disc, resulting in intervertebral disc degeneration (IVDD). Minimally invasive surgery can reduce the occurrence of paravertebral muscle atrophy.

3.3. Intervertebral Disc

The intervertebral disc (IVD) is a complex organ composed of fibrous and cartilaginous connective tissue. It serves as the boundary between two adjacent vertebrae, providing limited range of motion in the torso and stability during axial compression, rotation, and bending. Disruption of the stability of the spine can easily lead to Intervertebral Disc Degeneration (IVDD)[37].Liu X et al[38]simulated the asymmetrical removal of lumbar intervertebral discs to mimic asymmetrical degeneration and decreased intervertebral space height. They observed an increased asymmetry in the pressure of the facet joints, indicating that with asymmetrical degeneration of the lumbar intervertebral disc, the pressure on the facet joints significantly increases, and as time goes on, the degeneration of the facet joints becomes more severe. Some studies[39]have demonstrated that both partial and complete removal of the nucleus pulposus result in a notable increase in the range of motion (ROM) of the lumbar spine motion segment. Significantly greater segmental motion increase is observed after complete removal of the nucleus pulposus compared to partial removal. Hence, the augmentation in segmental ROM is associated with the extent of nucleus pulposus removal. The degenerative changes of the intervertebral disc are related to the damage of nearby structures, such as ligaments, joints, and paravertebral muscles, and the degenerative changes of the intervertebral disc will further exacerbate the degeneration of the surrounding spinal structures.

In conclusion, the functions of these components around the spine are interrelated. Changes in the structure after surgery may affect the load-bearing and movement characteristics of the spine, leading to increased back pain, intervertebral disc protrusion, or accelerated segmental degeneration, thereby causing spinal instability.

4. Unilateral Biportal Endoscopic

As a minimally invasive surgical technique, the UBE decompression surgery has been used for over 10 years to treat lumbar disc herniation and spinal stenosis[40-43].Compared with other minimally invasive surgical techniques, the UBE technology has several advantages. Firstly, surgeons can handle surgical instruments as in open surgery, without being limited by the working channel or tubular retractor[44].Secondly, the diameter of the endoscope used in UBE technology is only 4 millimeters. Surgeons can advance the endoscope very close to the lesion, even entering the contralateral lateral recess or intervertebral foramen. The closer the surgeons are to the lesion, the smaller the laminotomy window required for adequate decompression. UBE uses the gap between the muscles of the waist and a continuous expander to separate the muscles. With the inflow of physiological saline, a small space is created and can be used[45].By using water as a medium and high-definition endoscopes, the possibility of nerve tissue damage and dura mater damage is reduced[46].In addition, continuous flushing provides a clean surgical area by washing away bone fragments or other removed tissues, while applying static water pressure to exposed cancellous bone or venous plexus reduces epidural bleeding to provide a clean surgical area[47].The ligamenta flava is the necessary route to expose the lamina. When using the UBE to break through the ligamenta flava, the method of making a longitudinal incision along the ligamenta flava to enter the spinal canal allows the opening of the ligamenta flava to naturally close after the surgery and removal of the working channel, thus minimizing damage to the ligamenta flava. To avoid segmental instability after decompression, it is necessary to maintain the integrity of the facet joints as much as possible when performing complete nerve decompression. With the use of UBE technique, more than 80% of the facet joints on the entry side and more than 90% of the facet joints on the opposite side can be preserved[48],educing the risk of facet joint injury to a minimum. During the treatment of intervertebral disc protrusion, the annulus fibrosus can be sutured to accelerate healing, restore its normal function, and reduce the risk of re-protrusion.

As an emerging technology, UBE offers clear advantages in minimally invasive procedures compared to traditional open surgery. The dual-channel technique provides a wide field of view, enabling surgeons to operate more flexibly during the procedure. Continuous flushing with a water medium can maintain a clear field of view and reduce the risk of infection. Importantly, UBE causes less damage to the surrounding spinal structures during full decompression, thereby having a smaller impact on spinal stability. Current studies demonstrate that UBE has significant short-term efficacy for lumbar disc herniation and performs well in ensuring spinal stability. However, there is still a lack of sufficient evidence regarding the long-term efficacy and spinal stability. Consequently, more large-sample, multicenter prospective studies are needed in the future to verify the efficacy of UBE, which will facilitate a better understanding of its long-term impact.

References

[1] Wu P H, Kim H S, Jang I T. Intervertebral Disc Diseases PART 2: A Review of the Current Diagnostic and Treatment Strategies for Intervertebral Disc Disease[J]. Int J Mol Sci, 2020, 21(6).

[2] Benzakour A, Benzakour T. Lumbar disc herniation: long-term outcomes after mini-open discectomy[J]. Int Orthop, 2019,43 (4): 869-874.

[3] Liu Z M, Lu C C, Shen P C, et al. Suramin attenuates intervertebral disc degeneration by inhibiting NF-kappaB signalling pathway[J]. Bone Joint Res, 2021,10(8):498-513.

[4] Phillips K L, Jordan-Mahy N, Nicklin M J, et al. Interleukin-1 receptor antagonist deficient mice provide insights into pathogenesis of human intervertebral disc degeneration[J]. Ann Rheum Dis, 2013,72(11):1860-1867.

[5] Melrose J, Shu C, Young C, et al. Mechanical destabilization induced by controlled annular incision of the intervertebral disc dysregulates metalloproteinase expression and induces disc degeneration[J]. Spine (Phila Pa 1976), 2012,37(1):18-25.

[6] Jang J W, Lee D G, Park C K. Rationale and Advantages of Endoscopic Spine Surgery[J]. Int J Spine Surg, 2021,15(suppl 3):S11-S20.

[7] Gille O, Jolivet E, Dousset V, et al. Erector spinae muscle changes on magnetic resonance imaging following lumbar surgery through a posterior approach[J]. Spine (Phila Pa 1976), 2007,32(11):1236-1241.

[8] Gejo R, Matsui H, Kawaguchi Y, et al. Serial changes in trunk muscle performance after posterior lumbar surgery[J]. Spine (Phila Pa 1976), 1999,24(10):1023-1028.

[9] Hu Z J, Fang X Q, Zhou Z J, et al. Effect and possible mechanism of muscle-splitting approach on multifidus muscle injury and atrophy after posterior lumbar spine surgery[J]. J Bone Joint Surg Am, 2013,95(24):e191-e192.

[10] Wang W, Li W, Chen Z. Risk factors for screw loosening in patients with adult degenerative scoliosis: the importance of paraspinal muscle degeneration[J]. J Orthop Surg Res, 2021, 16(1):448.

[11] Kennedy D J, Zheng P Z, Smuck M, et al. A minimum of 5-year follow-up after lumbar transforaminal epidural steroid injections in patients with lumbar radicular pain due to intervertebral disc herniation[J]. Spine J, 2018,18(1):29-35.

[12] Parker S L, Mendenhall S K, Godil S S, et al. Incidence of Low Back Pain After Lumbar Discectomy for Herniated Disc and Its Effect on Patient-reported Outcomes[J]. Clin Orthop Relat Res, 2015,473(6):1988-1999.

[13] Hasan S, Hartl R, Hofstetter C P. The benefit zone of full-endoscopic spine surgery[J]. J Spine Surg, 2019,5(Suppl 1): S41-S56.

[14] Storzer B, Schnake K J. Microscopic bilateral decompression by unilateral approach in spinal stenosis[J]. Eur Spine J, 2016, 25 Suppl 2:270-271.

[15] Alimi M, Hofstetter C P, Pyo S Y, et al. Minimally invasive laminectomy for lumbar spinal stenosis in patients with and without preoperative spondylolisthesis: clinical outcome and reoperation rates[J]. J Neurosurg Spine, 2015,22(4):339-352.

[16] Kreiner D S, Hwang S W, Easa J E, et al. An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy[J]. Spine J, 2014,14(1):180-191.

[17] Wang H F, Song Y, Wang N G. Clinical Comparative Study of Unilateral Bilateral-Channel Spinal Endoscope and Percutaneous Endoscope and Fenestration and Nucleus Pulposus Resection for the Treatment of Lumbar Disc Herniation[J]. Journal of Chinese Journal of Reparative and Reconstructive Surgery, 2022, 36(10): 1200-1206.

[18] Pao J L. A Review of Unilateral Biportal Endoscopic Decompression for Degenerative Lumbar Canal Stenosis[J]. Int J Spine Surg, 2021,15(suppl 3):S65-S71.

[19] Shu T, Wu D Q, Shen M. Research Progress of Different Minimally Invasive Spinal Canal Decompression in Lumbar Spinal Stenosis[J]. Chinese Journal of Reparative and Reconstructive Surgery, 2023, 37(07): 895-900.

[20] Wang W, Li W, Chen Z. Risk factors for screw loosening in patients with adult degenerative scoliosis: the importance of paraspinal muscle degeneration[J]. J Orthop Surg Res, 2021,16(1):448.

[21] Jaumard N V, Welch W C, Winkelstein B A. Spinal facet joint biomechanics and mechanotransduction in normal, injury and degenerative conditions[J]. J Biomech Eng, 2011,133 (7): 71010.

[22] Zhou Z Y, Wang J W, Zhang Y F, et al. Progress in the study of the relationship between joint hypermobility syndrome and lumbar instability. [J]. Chinese Journal of Traditional Chinese Orthopedics and Traumatology, 2018, 26(07): 81-83.

[23] Chen X F, Zhang T Y, Xu T M, et al. Research progress on diagnostic methods for lumbar instability. [J]. Chinese Journal of Spine and Spinal Cord, 2020, 30(02): 175-179.

[24] Studnicka K, Ampat G. Lumbar Stabilization[J]. 2024.

[25] Jaumard N V, Welch W C, Winkelstein B A. Spinal facet joint biomechanics and mechanotransduction in normal, injury and degenerative conditions[J]. J Biomech Eng, 2011,133 (7): 71010.

[26] Pao J L, Lin S M, Chen W C, et al. Unilateral biportal endoscopic decompression for degenerative lumbar canal stenosis [J]. J Spine Surg, 2020,6(2):438-446.

[27] Kiapour A, Ambati D, Hoy R W, et al. Effect of graded facetectomy on biomechanics of Dynesys dynamic stabilization system[J]. Spine (Phila Pa 1976), 2012,37(10): E581-E589.

[28] Zhao F, Liu Z, Wang B Q, et al. Influence of graded resection of lumbar facet joints on lumbar stability by finite element simulation of single-segment lumbar vertebrae. [J]. Chinese Medical Journal, 2015, 95(13): 973-977.

[29] Perolat R, Kastler A, Nicot B, et al. Facet joint syndrome: from diagnosis to interventional management[J]. Insights Imaging, 2018,9(5):773-789.

[30] Zhou Z Y, Zhang Y F, Zhou Y,et al. Evaluation of the effect of spinal manipulation on lumbar stability by quantitative X-ray measurement technique. [J]. Chinese Journal of Traditional Chinese Orthopedics and Traumatology, 2018, 26(01): 10-16.

[31] Heuer F, Schmidt H, Claes L, et al. Stepwise reduction of functional spinal structures increase vertebral translation and intradiscal pressure[J]. J Biomech, 2007,40(4):795-803.

[32] Li Y, Shen Z, Huang M, et al. Stepwise resection of the posterior ligamentous complex for stability of a thoracolumbar compression fracture: An in vitro biomechanical investigation[J]. Medicine (Baltimore), 2017,96 (35): e7873.

[33] Hodges P W, Danneels L. Changes in Structure and Function of the Back Muscles in Low Back Pain: Different Time Points, Observations, and Mechanisms[J]. J Orthop Sports Phys Ther, 2019,49(6):464-476.

[34] Wang X, Jia R, Li J, et al. Research Progress on the Mechanism of Lumbarmultifidus Injury and Degeneration[J]. Oxid Med Cell Longev, 2021,2021:6629037.

[35] Wang K, Deng Z, Chen X, et al. The Role of Multifidus in the Biomechanics of Lumbar Spine: A Musculoskeletal Modeling Study[J]. Bioengineering (Basel), 2023,10(1).

[36] Tsutsumimoto T, Shimogata M, Ohta H, et al. Mini-open versus conventional open posterior lumbar interbody fusion for the treatment of lumbar degenerative spondylolisthesis: comparison of paraspinal muscle damage and slip reduction [J]. Spine (Phila Pa 1976), 2009,34(18):1923-1928.

[37] Kirnaz S, Capadona C, Lintz M, et al. Pathomechanism and Biomechanics of Degenerative Disc Disease: Features of Healthy and Degenerated Discs[J]. Int J Spine Surg, 2021, 15 (s1):10-25.

[38] Liu X, Huang Z P, Zhu Q A, et al. The effect of asymmetrical discectomy on facet joint pressure and lumbar stability. [J]. Medical Biomechanics, 2016, 31(03): 261-265.

[39] Yang Z, Zhu Q A. Biomechanical research progress on lateral approach lumbar spine internal fixation. [J]. Medical Biomechanics, 2019, 34(06): 656-661.

[40] Hwa E J, Hwa H D, Son S K, et al. Percutaneous biportal endoscopic decompression for lumbar spinal stenosis: a technical note and preliminary clinical results[J]. J Neurosurg Spine, 2016,24(4):602-607.

[41] Torudom Y, Dilokhuttakarn T. Two Portal Percutaneous Endoscopic Decompression for Lumbar Spinal Stenosis: Preliminary Study[J]. Asian Spine J, 2016,10(2):335-342.

[42] Soliman H M. Irrigation endoscopic decompressive laminotomy. A new endoscopic approach for spinal stenosis decompression[J]. Spine J, 2015,15(10):2282-2289.

[43] Soliman H M. Irrigation endoscopic discectomy: a novel percutaneous approach for lumbar disc prolapse[J]. Eur Spine J, 2013,22(5):1037-1044.

[44] Eun S S, Eum J H, Lee S H, et al. Biportal Endoscopic Lumbar Decompression for Lumbar Disk Herniation and Spinal Canal Stenosis: A Technical Note[J]. J Neurol Surg A Cent Eur Neurosurg, 2017,78(4):390-396.

[45] Jiang H W, Chen C D, Zhan B S, et al. Unilateral biportal endoscopic discectomy versus percutaneous endoscopic lumbar discectomy in the treatment of lumbar disc herniation: a retrospective study[J]. J Orthop Surg Res, 2022,17(1):30.

[46] Jang J W, Lee D G, Park C K. Rationale and Advantages of Endoscopic Spine Surgery[J]. Int J Spine Surg, 2021,15(suppl 3): S11-S20.

[47] Heo D H, Quillo-Olvera J, Park C K. Can Percutaneous Biportal Endoscopic Surgery Achieve Enough Canal Decompression for Degenerative Lumbar Stenosis? Prospective Case-Control Study[J]. World Neurosurg, 2018, 120: e684-e689.

[48] Aygun H, Abdulshafi K. Unilateral Biportal Endoscopy Versus Tubular Microendoscopy in Management of Single Level Degenerative Lumbar Canal Stenosis: A Prospective Study[J]. Clin Spine Surg, 2021,34(6): E323-E328.