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Article

The biomechanical therapeutic effects of cilateral biportal endoscopic treatment of lumbar spondylolisthesis

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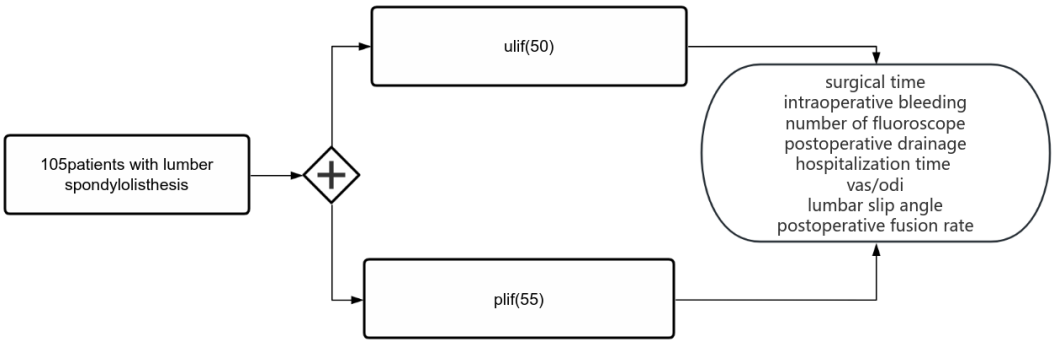
Abstract: Purpose: To compare the therapeutic effects of unilateral biportal endoscopic lumbar interbody fusion (ULIF) using a 3D printed cage and posterior lumbar interbody fusion (PLIF) using a 3D printed cage in the treatment of lumbar spondylolisthesis. **Method:** To retrospectively analyze the clinical data of 105 patients with lumbar spondylolisthesis in Qianfoshan Hospital of Shandong Province from Among them, 50 cases were treated with ULIF (ULIF group) and 55 cases were treated with PLIF (PLIF group). The operation time, intraoperative blood loss, postoperative drainage volume, hospitalization days, postoperative complications, waist and leg pain vas scores, and OSTC pain scores, were all measured. The operation time, intraoperative blood loss, postoperative drainage volume, hospitalization days, postoperative complications, waist and leg pain vas scores, and Oswestry Disability Index (ODI) were compared between the two groups. **Results:** The operation time in the ULIF group was longer than that in the PLIF group, and the difference was statistically significant ($p < 0.05$). There were statistically significant differences in intraoperative blood loss, postoperative drainage volume, and hospital stay ($p < 0.05$). There were 1.1 cases of cerebrospinal fluid leakage in the ULIF group and the PLIF group after surgery, and 3 cases of infection in the PLIF group. No other complications occurred. No other complications occurred. The difference in the incidence of complications between the two groups was statistically significant ($p < 0.05$). Patients in both groups were followed for 6 to 12 months. In the ULIF group and the PLIF group using 3D printed intervertebral fusion cages, the intervertebral fusion rates were as high as 1 to 1.5 times the intervertebral fusion rate. In the ULIF group and the PLIF group using 3D printed intervertebral fusion cages, the intervertebral fusion rates at 6 months (80%/81.8%, $p > 0.05$) and 12 months (96%/96%, $p > 0.05$) after surgery were statistically undifferenced. **Conclusion:** For patients with lumbar spondylolisthesis, ULIF group can achieve similar efficacy to PLIF group using a 3D printed fusion cage. They are similar in terms of pain relief and improvement in functional disability. ULIF group has less intraoperative and postoperative bleeding and shorter hospitalization days, lower infection rate and less damage to muscle tissue. ULIF has less intraoperative and postoperative bleeding and shorter hospitalization days, lower infection rate and less damage to muscle tissue. However, ULIF takes a long time, has a long learning curve and requires high equipment.

Keywords: lumbar spondylolisthesis; endoscopic lumber fusion; unilateral biportal endoscopic lumbar interbody fusion; posterior lumbar interbody fusion 3D printed fusion cage



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1. Research introduction

Lumbar spondylolisthesis (DLS) is defined as a slip of one vertebra relative to another. Lumbar spondylolisthesis causes low back pain, neurogenic claudication, and is a major cause of lower limb paralysis in middle-aged and elderly people, and with the further development of an aging society, lumbar spondylolisthesis will become a major health threat. With the further development of the aging society, lumbar spondylolisthesis will become a major health threat, conventional open surgery exists with muscle stripping and pulling will lead to significant muscle damage and atrophy, in recent years to reduce the surgical minimally invasive techniques of medical origin damage favored by the patients and doctors. In this study, we used a retrospective approach to compare unilateral two-channel endoscopic lumbar fusion (ulif) using a 3D-printed fusion device with posterior approach lumbar fusion (plif) using a 3D-printed fusion device for the treatment of lumbar spondylolisthesis in terms of hemorrhage, operative time, hospital stay, drainage, postoperative complications, VAS scores for low back and leg pain, and oswestry dysfunction index (ODI). The results, fusion rate analysis of the advantages, disadvantages and clinical efficacy of the two surgical procedures are reported as follows.

2. Data and methods

2.1. Inclusion criteria

(1) Lumbar spondylolisthesis diagnosed by preoperative X-ray, magnetic resonance imaging (MRI) and CT, and the etiology analyzed to be degenerative; (2) Clinical manifestations of typical lumbar and leg pain, intermittent claudication, or accompanied by lower extremity radicular nerve symptoms and signs, with no significant improvement of the symptoms and lumbar pain could not be relieved by regular non-surgical treatments for more than 6 months [1,2]. The clinical symptoms were typical of lumbar and leg pain, with no significant improvement of symptoms [1,2]. (3) First time surgical treatment. Exclusion criteria: (1) History of lumbar spine surgery. (2) Patients referred with severe comorbidities. (3) Lower limb paralysis or presence of cauda equina syndrome. (4) Postoperative loss of visits [3,4].

The clinical data of 105 elderly patients with lumbar spinal stenosis who met the selection criteria from April 2021 to December 2023 at Qianfoshan Hospital in

Shandong Province were retrospectively analyzed. Among them, 50 cases were treated with spinal endoscopic fusion using 3d printed fusion device (ULIF group) and 55 cases were treated with lumbar fusion using posterior approach with 3d printed fusion device (PLIF group). The baseline data of the two groups such as basic information (age gender height and weight), time of illness and preoperative lumbar and leg pain scores, dysfunction index, total slipped segments were the same (slipped angle, intervertebral space height vertebral canal width and other baseline data were compared, and the difference was not statistically significant ($p > 0.05$).

2.2. Inclusion criteria

There were 105 cases in this group, 51 male and 54 female, aged 45–72 years, average 60 years. Clinical manifestations were mainly lumbar pain or lower limb radiating pain, which was accompanied by intermittent claudication in 4 cases, sensory abnormality in 15 cases, and decreased muscle strength in 3 cases, and all of the patients were ineffective after strict systematic conservative treatment for more than 6 months, with progressive aggravation of symptoms. Preoperative X-ray films of lumbar spine in front and side position, hyperflexion and hyperextension power position, CT or MRI of lumbar spine were taken. According to Mexerding classification: 80 cases of I degree slip, 19 cases of II degree slip, 6 cases of III degree slip; 4 cases of L2 slip, 10 cases of L3 slip, 31 cases of L4 slip, 60 cases of L5 slip, and 50 cases of multi-segmental slip. MRI suggested that the intervertebral discs had different degrees of degeneration, among which there were 80 cases of combined spinal stenosis, and 98 cases of combined intervertebral disc herniation. A total of 85 lesions were treated in the ulif group, and 85 lesions were treated in the pilf group. In the ulif group, a total of 85 diseased vertebrae were treated, ensuring the same number of segments.

Table 1

	age	**man**	**woman**	**Unilateral symptoms**	**Bilateral symptoms**
ulif	52.8 ± 13.1	24	26	20	30
plif	54.8 ± 11.2	27	28	21	34
p	0.382	0.912		0.851	

2.3. Surgical methods

Both groups were operated by the same group of physicians, and the patients were operated in the prone position under general anesthesia.

ULIF group: C-arm fluoroscopy was used to determine the position of the vertebral interspace and the pedicle of the target segment. Sterilization of the sheet, under c-arm fluoroscopy along the arch root penetration guidewire, to the right side, for example, in the responsible intervertebral space above and below the 1.5 cm positioning point to cut a small incision, the incision is located in the line of the upper and lower arch root medial side, the cephalad incision for the upper vertebral plate caudal side, the caudal side of the incision from the cephalad incision of 2.5–3.0 cm. step by step socket dilatation, the establishment of the operation channel and the observation channel. Ipsilateral decompression: radiofrequency treatment of the

dorsal soft tissues of the vertebral plate, gradually reveal the intervertebral window, use a grinding drill, a bone knife, and a spatula to remove the lower edge of the cephalad vertebral plate, the inner edge of the articular eminence, and the upper edge of the caudal vertebral plate in order to gradually reveal the stopping point of the ligamentum flavum; then use a spatula to peel the stopping point of the ligamentum flavum away from the vertebral plate, and the vertebral plate biting forceps and the nucleus pulposus forceps to remove the dorsal white part of the ligamentum flavum and retain the ventral yellow part of the ligamentum flavum, to fully reveal the nerve root shoulder and axilla The lateral saphenous fossa is decompressed and the distal end of the lateral saphenous fossa is explored. After destroying the intervertebral disc with a progressive reamer, the nucleus pulposus was extracted with a nucleus pulposus forceps, the inner edge of the apical portion of the superior articular eminence was adequately removed, and the cartilaginous endplates were scraped with a scraping spoon, preserving the osseous endplates. Intervertebral bone grafting was performed with a bone grafting device, and an appropriately sized 3d printed fusion device was implanted. After sufficient nerve exploration and dural decompression, percutaneous pedicle screws were implanted under C-arm X-ray fluoroscopy. After adequate hemostasis, drainage was placed and the incision was closed (**Figures 1–4**) [25–27].

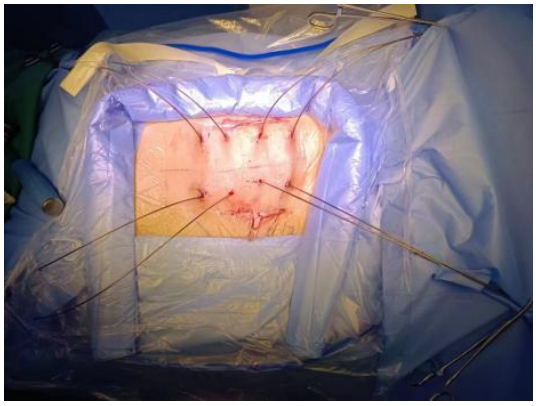

Figure 1. Percutaneous puncture to identify the pedicle and insert the guidewire.

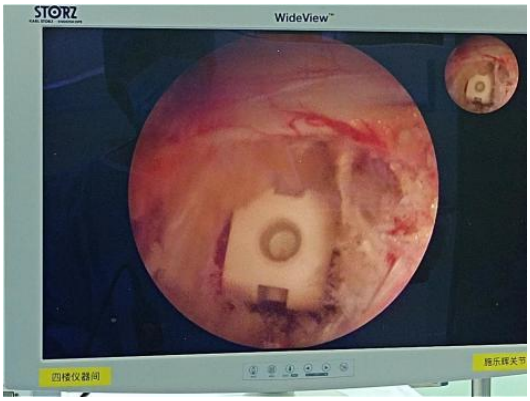

Figure 2. Treatment of the gap and placement of the fusion device.

Figure 3. Insertion of pedicle screws.

Figure 4. Postoperative fluoroscopy of the front and side positions to determine the solid internal fixation and good position of the fusion device.

PLIF group: the responsible space was determined under fluoroscopy, the sheet was sterilized, the skin was incised along the spinous process in the posterior median, the deep fascia was incised, the paraspinal muscles were peeled off under the periosteum, and the vertebral plate and articular synchondrosis were exposed. The pedicle screws were placed bilaterally, and good position of the screws was determined by fluoroscopy. The plate of the superior vertebra and the medial portion of the bilateral articular synchondrosis were removed, and after removing the ligamentum flavum, the dural sac and nerve roots were exposed, and the nerve tissue was retracted to expose the intervertebral discs. After revealing the bony structure, the vertebral plate of the superior vertebral body is completely removed, the medial portion of the articular eminences is removed bilaterally, the dural sac and nerve roots are revealed after removing the ipsilateral ligamentum flavum, and the intervertebral discs are revealed after retracting the dural sacs and walking the nerve roots toward the midline. The diseased disc was resected, and the nucleus pulposus and endplate cartilage were scraped with a spatula, and the autogenous fragmented bone block and the appropriate size of 3d printed fusion device were implanted after adequate rinsing. Bilateral rods were installed, the nail-rod system was adjusted, and fixation was completed by re-fluoroscopy to confirm that the fusion device was in good position. Find the bleeding point and carefully stop the bleeding, leave the drainage tube, and suture the incision [28–30].

2.4. Evaluation indicators

Perioperative indicators were recorded, including: operation time, intraoperative bleeding, total length of incision, number of intraoperative fluoroscopies, postoperative drainage, hospitalization days, and incision healing, and the occurrence, management and regression of postoperative complications were recorded. Pain visual analogue scale (VAS), Oswestry disability index (ODI), and outcome were used. For imaging, lumbar slip angle, intervertebral space height, spinal canal width, fusion rate were measured, and postoperative x-rays were reviewed at 3/6/9 months after surgery to observe the postoperative slip angle. Implant fusion was assessed using the SUK criteria: (1) strong fusion, with continuous bone trabeculae passing through the fusion area, and intersegmental relative motion <4° on dynamic-slice radiographs: (2) probable fusion, with continuous bone trabeculae in the fusion area that were not clearly observed. Intersegmental activity <4° on dynamic position radiographs. And (3) No fusion, intersegmental activity >4° on dynamic position radiographs. The evaluation of the above imaging results was conducted by two radiologists and one orthopedic surgeon. The evaluators have no conflict of interest with the study and are not aware of any information other than the imaging results of the evaluated individuals

2.5. Statistical methods

SPSS 23.0 statistical software was applied All evaluation indexes preoperative and postoperative follow-up data were analyzed using $x \pm s$. The paired *t*-test was performed, and <0.05 was set as a significant difference.

Table 2

Evaluation indicators	Surgical time (min)	Intraoperative bleeding (ml)	Number of fluoroscopy (times)	Postoperative drainage (mi)	Hospitalization time (d)
ulif	170.90 ± 8.43	148.52 ± 23.44	27.22 ± 4.59	120.82 ± 16.50	7.60 ± 0.78
plif	119.09 ± 7.70	196 ± 24.15	8.50 ± 1.38	232.36 ± 33.58	12.65 ± 2.41
P-value	$P < 0.00001$	$P < 0.00001$	$P < 0.00001$	$P < 0.00001$	$P < 0.00001$

3. Results

3.1. Perioperative data

Preoperatively, all patients practiced urination with urinary basin in bed, smoking patients stopped smoking, practiced coughing, enhanced nutrition, hypertensive patients controlled blood pressure with antihypertensive drugs, diabetic patients controlled blood glucose with insulin, painkillers controlled pain, and prohibited from drinking and fasting before surgery.

All the patients completed the surgery successfully, the duration of the surgery was 2 h–4 h, average 2.5 h, and there were no complications such as hematoma formation, nerve damage, sensory abnormality and weakness, etc. There was one case of cerebrospinal fluid leakage in the ulif group, and the symptom was improved after giving rehydration solution of mannitol and elevation of the end of the bed, and the headache was alleviated, and the three patients in the Plif group had infections, and the

symptoms were improved after being given antibiotics after the surgery. Three patients in the Plif group developed infection, which improved after antibiotic treatment. Three patients developed vomiting symptoms after surgery, one in the ulif group and two in the plif group, which improved after the administration of onsetron hydrochloride; there was no recurrence of symptoms of incomplete decompression, nerve injury leading to cauda equina syndrome, and loosening of built-in objects. There was no redness, swelling or large scar tissue affecting the aesthetics of the surgical incisions in both groups, and they all healed well to achieve Grade A healing. The patients could perform extension and flexion activities of the lower limbs after 2–3 h after the operation. The ulif group was discharged from the hospital 6–7 days after the operation and the plif group was discharged from the hospital 10–14 days after the operation, and the patients resumed their normal work after 3–6 weeks after discharge from the hospital. All patients were fitted with lumbar external fixation to maintain lumbar stability after surgery. ulif was significantly better than plif in terms of intraoperative bleeding, postoperative drainage, and hospitalization time ($P < 0.05$).

3.2. Follow-up results

All patients were followed up for 6–12 months, with a mean follow-up time of (8.4 ± 2.7) months. Both groups recovered well after the operation, with reduced pain and a significant decrease in vas score and odi index, but the difference between the two groups was not statistically significant ($P > 0.05$). During the follow-up period, there were no patients who required reoperation due to recurrence or loosening of internal fixation in both groups.

Table 3. Comparison of VAS score and ODI index in 45 patients at the last follow-up after surgery.

Index	ulif	plif	*P* value
vas score	1.34 ± 0.47	1.32 ± 0.47	0.891
Odi index	7.46 ± 0.50	7.56 ± 0.50	0.293

3.3. Imaging assessment

The imaging assessment data are shown in **Table 2**. Compared with the preoperative period, at 12 months postoperatively, the lumbar slip angle was significantly reduced, the intervertebral space height, and the area of the spinal canal were significantly improved in both groups, and the difference was statistically significant ($P < 0.05$), and the differences in lumbar slip angle, intervertebral space height, anterior and posterior diameter of the spinal canal, and fusion rate were not statistically significant when comparing the two groups at the corresponding time points ($P > 0.05$).

These results were jointly obtained by two radiologists and one orthopedic surgeon using radiological blinding.

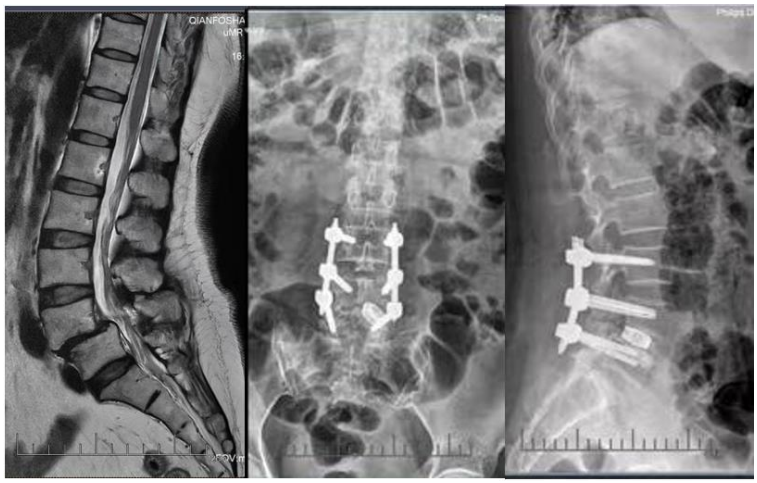

Figure 5. Pre-operative imaging and post-operative review of X-ray alignment and post-operative review of X-ray lateral position.

Table 4

Indicators	Lumbar slip angle	Intervertebral space height	Anteroposterior diameter of the spinal canal	Postoperative fusion rate 6 months	Postoperative fusion rate 12 months
12 months after operation in ulif group.	1.16 ± 0.07	8.32 ± 0.26	16.9 ± 2.59	40/50	48/50
12 months after operation in Plif group.	1.14 ± 0.12	8.22 ± 0.13	17.81 ± 2.68	45/55	53/55
P value	0.415	0.016	0.79	0.815	0.923

4. Discussion

By comparing the related indexes of 105 patients, this study found that when dealing with the diseases of patients with lumbar spondylolisthesis.

At present, when dealing with the disease of lumbar spondylolisthesis, most hospitals still use posterior approach lumbar fusion, which can deal with most problems, relieve pain and improve dysfunction, but it also has the disadvantage of destroying the muscles and bone structures of the back, which often leads to severe intractable pain in the back. In order to solve these problems, various minimally invasive methods have gradually emerged. We treat patients with lumbar spondylolisthesis with unilateral and double-channel spinal endoscopic fusion. We take four 2 cm holes in the back of the waist, treat the gap with a mirror, and fix the gap with a percutaneous nail, which preserves the integrity of muscle and bone tissue. The most important thing in the operation is the step of treating the intervertebral space under the mirror, and the most important thing is to be familiar with the anatomical structure under the mirror, so as not to lose the direction of the mirror and the operating channel. After establishing the preliminary operating space, we can make sure that the gap is correct. Bone structure should be treated with osteotome and grinding drill, yellow ligament fat and nucleus pulposus should be treated with nucleus pulposus forceps and electrotome. When the endplate is treated under microscope, care should be taken not to damage the bony endplate and anterior longitudinal ligament, and then the fusion cage should be implanted. When implanting the fusion cage, care should be taken to avoid continuous washing to prevent bone

fragments from being lost. Many literatures believe that endoscopic fusion is a minimally invasive operation with definite curative effect.

Spinal endoscopic fusion is as effective as traditional open fusion and internal fixation, and it has advantages in incision size, muscle damage, blood loss, time to get out of bed, discharge time and infection rate [5–7]. In terms of surgical incisions, ulif adopts four small incisions rather than one large incision, the transverse small incisions are often parallel to the skin pattern, which is easier to recover and at the same time the length of the incision is smaller than that of the longitudinal incision, because endoscopic treatment of diseased tissues maximizes the preservation of muscular tissues of the lumbar back and the bony structures, therefore, in terms of the amount of bleeding and the drainage flow in the postoperative period, the endoscopic surgery is more dominant [8,9] and the small destruction of muscles also accelerates the discharge and bedtime of patients, and the principle is similar to the "bullnose drainage method" to control infection. The endoscopic procedure uses constant saline lavage, which is similar in principle to the "bullnose drainage" method of infection control, as bacteria are unable to multiply and grow rapidly in the active sterile saline. Endoscopic spinal fusion surgery is often difficult to differentiate from posterior lumbar fusion in terms of surgical outcomes. VAS scores and ODI scores improved dramatically in both groups at 12 months after surgery, with no statistical significance in comparison, and ulif and plif fusion rates were approximately the same [14,20–22] Posterior lumbar spinal fusion and endoscopic fusion are useful in helping lumbar spine slippage patients with pain relief, bone misalignment and repositioning. Both procedures were equally effective in relieving pain, repositioning bony subluxations, and restoring intervertebral space height, with no recurrence of symptoms in the perioperative period or during follow-up. The unilateral dual-channel spinal endoscopy has many advantages, such as (1) the fusion device is inserted through a channel instead of a working trocar, so that a large-sized fusion device can be inserted into the intervertebral space (2) the ulif is operated under the microscope from the beginning to the end, and there is a continuous saline lavage to provide a clear field of vision, which can enlarge the field to provide a clear image (3) it is less destructive to the muscular tissues, and most of the posterior structures are retained, so that the postoperative intractable low back pain is avoided [10]. Low back pain [10,11], (4) Surgical instruments and operating channels can be moved independently, which increases the flexibility of the operation, and the field of vision and operation is not limited, so that the stenosis of the central spinal canal and intervertebral foramen can be treated directly, and the detailed treatment of the endplates can be realized to reduce endplate injuries.

Due to the long learning curve and complexity of unilateral dual-channel spinal endoscopic fusion, there are many complications, including dural tear, postoperative hematoma, sinking and retraction of the fusion device, nerve root injury, and aquatic complications (e.g., peritoneal effusion, hypothermia, headache, seizure, and neck stiffness). ① Dural tears are usually treated with a collagen patch, and should be directly sutured under the endoscopy if they are larger than 10 mm or repaired by microsurgery. The reason for postoperative hematoma is that unilateral dual-channel spinal endoscopy is performed under the water channel, and there is water pressure to

counteract it during surgery, so small bleeding points with ruptured blood vessels are not easy to be detected because they are suppressed by the water pressure and do not bleed. In order to avoid postoperative hematoma, we should carefully search for the bleeding points during the surgery and before suturing, and the bleeding on the bone surface should be coated with bone wax, and the part of the fibrous ring incision should be covered with fluid gelatin or gelatin sponge, and a proper drainage tube should be used for the bleeding points. Use appropriate drainage tubes, for patients who have been taking aspirin for a long time, pay attention to coagulation factors before surgery, stop using anticoagulant drugs or change anticoagulant drugs, if the hematoma causes radicular symptoms inadvertently after surgery, the ubeogenous access should be used to clear the hematoma, (3) The general cause of fusion sinking is the destruction of the bony endplates, when dealing with the endplates of the patients, reduce the use of the spatula, and use the endplate removers and double-ended strippers more often, especially for patients with osteoporosis. This is especially important in osteoporotic patients. Lateral placement of the fusion device and the use of pedicle screws for compression while locking the screws after the fusion device has been placed can avoid the occurrence of fusion device subsidence. 4) Avoid nerve root injury, first of all, familiarize yourself with the anatomical structure of the mirror, understand what the nerve looks like under the mirror, avoid mis-cutting, avoid the use of sharp tools, and avoid the traction injuries resulting from excessive pulling of the nerve. 5) Headache, neck stiffness, epilepsy, and other common problems. headache, neck stiffness, epilepsy occurs due to continuous water perfusion caused by increased intracranial pressure, which in turn triggered on the neck pain, stiffness as a precursor symptom, followed by headache, tinnitus, visual disturbances, sense of dying, epileptic symptoms, most often in lumbar anesthesia or local anesthesia to do ube, ulif surgery rarely occurs, to do the ube, when the patient has a headache, neck stiffness, you can give the patient to reduce the symptoms of massage If epilepsy occurs, the surgery should be stopped immediately, but the main concern is to control the duration of the surgery. The longer the duration of the surgery, the higher the probability of epilepsy, headache, and neck stiffness, and epilepsy occurs in 96 min on average. 6) Abdominal or thoracic effusion is a problem that may occur during a paravertebral approach, which is caused by disruption of the transverse processes and ligaments, and is the first thing that can be detected by the patient when it occurs. In the case of a pleural effusion, the anesthesia machine will also report elevated airway pressures, which will require that the surgery be terminated as soon as possible and the patient be transported to the appropriate specialty for further treatment, such as medication or puncture of the effusion. (7) Chilliness, or postoperative chills, is another aquatic complication. The use of saline lavage during surgery lowers the patient's body temperature, which often leads to chills and postoperative shivering. This can be achieved by switching to warmer saline or using a warming blanket, and by controlling the duration of the surgery to avoid prolonged lavage under the water stream.

Spinal endoscopic fusion surgery also has many limitations, such as high instrumentation requirements, many hospitals are not equipped with arthroscopes, indications are not broad, many patients with severe slips, deformities, and spinal stenosis are difficult to deal with, the learning curve is long, and the radiation exposure

time is long, which can be a threat to the health of medical workers. In terms of operative time, ulif is much longer than plif [12], due to the high number of fluoroscopies and complexity of operations in ulif. Traditionally, endoscopic fusion surgery has the advantage of being minimally invasive and easier for patients to accept. However, it also has the disadvantages of complicated operation, unclear field, and high requirement of instrumentation. No study can prove that minimally invasive endoscopic fusion can completely replace traditional surgery, and open surgery is still the mainstream surgery for the treatment of lumbar spondylolisthesis most of the time [13]. However, with the progress of aging and the increase of elderly patients with lumbar spondylolisthesis, spinal endoscopic spinal decompression fusion will gradually develop and become another important treatment modality for lumbar spondylolisthesis [5,7]. The traditional surgical approach has problems such as high intraoperative bleeding, postoperative incision infection, loosening of the endoprostheses, and fusion failure. While spinal endoscopic fusion can reduce the incidence of these problems or decrease the severity of these complications, open surgical procedures tend to have greater trauma, larger decompression areas, and higher reoperation rates, which in turn affects the patient's prognosis [16,17]. In order to solve this problem, a series of minimally invasive spinal decompression surgical procedures have come into existence, and in recent years there have been intervertebral foraminoscopes, unilateral dual-channel spinal endoscopes, the posterior access channels, and have gained increasing acceptance. Unilateral dual-channel endoscopic fusion, as one of these emerging minimally invasive techniques, has the advantages of minimal tissue damage, low complication rate, and rapid recovery, and is becoming increasingly popular among spine surgeons [18,19]. Traditional surgery has extensive intraoperative muscle stripping, and muscle destruction, and spinal endoscopic fusion protects structures such as paravertebral muscles and achieves adequate decompression while maintaining better stability, which reduces postoperative pain, increases patient comfort, and reduces patient hospitalization time. This study proved that spinal endoscopic fusion is as effective as traditional open decompression and fusion with internal fixation in treating patients with lumbar spondylolisthesis in a short period of time, and at the same time, spinal endoscopic fusion has the advantages of low infection rate, quick discharge from the hospital, less bleeding, and less tissue destruction, which means that this surgical procedure is safer than the traditional open decompression and fusion with internal fixation. With the continuous development and popularization of the technology, endoscopic fusion will continue to occupy a greater proportion of surgery [23].

The cost of ulif is usually higher than conventional surgical procedures, as arthroscopic surgery often requires the introduction of expensive equipment, which hinders the further promotion of the surgery, The long learning curve of endoscopic surgery hinders its further promotion, and the long operation time increases the risks of surgery and the fatigue of doctors, all of which require further exploration of better treatment methods

Compared with traditional craftsmanship, using 3D printing technology to manufacture. The advantages of sexual surgical implants are mainly reflected in the freedom of 3D printing. The molding feature allows for quick and precise customization of internal implants, which can. To overcome the incompatibility

between the shape of traditional universal implants and the human body.

The problem of substandard mechanical properties; In the presence of complex structures and when manufacturing difficult to process products, personalized customization of microstructure is particularly important. It is a porous and interconnected structure that can not only meet specific physical and chemical properties. It can also enhance the compatibility of biological tissues. This series of advantages can effectively overcome the stress shielding and biological activity commonly present in implants low difficulty. Currently, 3D printed titanium alloys are commonly used and widely applied is SLM technology and EBM technology.

Shortcomings of this study

This study is a retrospective analysis that increases the risk of bias. Prospective analysis can be conducted in the future, while avoiding excessive promotion of endoscopic surgery that may lead patients to choose specific treatment plans. This study is a retrospective cohort study with a small number of sample cases, which cannot accurately reflect the difference in efficacy between the two, and the postoperative follow-up by telephone is prone to missing visit bias and some patients are unable to obtain postoperative imaging data. The short follow-up period can only determine the clinical efficacy in the early stage, and it is not possible to include the long-term complications such as adjacent segment syndrome in the study. In the future, more cases should be included, more complete and scientific experiments should be designed, and longer follow-up should be conducted to verify the effectiveness and safety of this procedure, longer follow-up is also needed to determine the impact of fusion on other stages. vas scoring has a certain degree of subjectivity and may not necessarily reflect the true pain relief effect.

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Ethical approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Shandong Province Qianfoshan Hospital.

Conflict of interest: The authors declare no conflict of interest.

References

1. Wan J, Wang N, Bei C, et al. Two lumbar fusion regimens in treatment of single-level lumbar degenerative diseases based on propensity score matching. Chinese Tissue Engineering Research. 2024; 28(12): 1914-1919. doi: 10.12307/2024.061
2. Sang L, Liu S, Zhao Z. Comparison of clinical efficacy between unilateral dual-channel endoscopically assisted posterior

lumbar interbody fusion and conventional posterior lumbar fusion. Bio-Orthopaedic Materials and Clinical Research. 2024; 21(05): 15-20.
3. Lu H, Tian L, Hu P, et al. Short-term clinical efficacy analysis of unilateral dual-channel endoscopic treatment of lumbar spinal stenosis in a single responsible segment. Chinese Journal of General Practice. 2023; 21(3): 413-416. doi: 10.16766/j.cnki.issn.1674-4152.002896
4. Wang J. Clinical efficacy analysis of MIS-TLIF and PLIF in the treatment of two-segment degenerative lumbar spinal stenosis. Jilin University; 2023.
5. Cao S, Fan B, Song X, et al. Oblique lateral interbody fusion (OLIF) compared with unilateral biportal endoscopic lumbar interbody fusion (ULIF) for degenerative lumbar spondylolisthesis: a 2-year follow-up study. Journal of Orthopaedic Surgery and Research. 2023; 18(1). doi: 10.1186/s13018-023-04111-x
6. Zhang WW. Clinical efficacy analysis of unilateral dual-channel endoscopic intervertebral implant fusion and internal fixation for lumbar spondylolisthesis [xxx]. Zunyi Medical University; 2023.
7. Wang H, Wu Z. Comparison of single-channel Delta endoscopy and unilateral double-channel endoscopy in the treatment of senile lumbar spinal stenosis. Journal of Xi'an Jiaotong University (Medical Edition). 2021; 42(06): 797-801.
8. Gu Y, Li Y, Xie W, et al. Clinical analysis of unilateral and dual-channel spinal endoscopy in the treatment of lumbar spinal stenosis. International Journal of Orthopaedics. 2021; 42(05): 323-328.
9. Huang X. Technical improvement of double-channel spinal endoscope and clinical study of lumbar interbody fusion [xxx]. PLA Army Medical University; 2023.
10. Huang X, Wang W, Chen G, et al. Comparison of surgical invasiveness, hidden blood loss, and clinical outcome between unilateral biportal endoscopic and minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative disease: a retrospective cohort study. BMC Musculoskeletal Disorders. 2023; 24(1). doi: 10.1186/s12891-023-06374-1
11. Miao S, Han P, Xu L. Analysis of curative effect of full-view spine endoscopy in the treatment of lumbar disc herniation with lateral recess stenosis. China Journal of Modern Surgery. 2022; 26(4): 277-281.
12. Wang Q, Zhang QZ, Peng Y, et al. Effect of lumbar interbody fusion under unilateral double-channel endoscope on paraspinal muscles. China Tissue Engineering Research. 2024: 1-7.
13. Wang H. Comparison of the efficacy of endoscopic spinal fusion and traditional open TLIF for the treatment of single-segment lumbar degenerative disease [xxx]. Jilin University; 2023.
14. de Kunder SL, Rijkers K, Caelers IJMH, et al. Lumbar Interbody Fusion. Spine. 2018; 43(16): 1161-1168. doi: 10.1097/brs.0000000000002534
15. Sang L, Liu S, Zhao Z. Comparison of clinical efficacy of unilateral dual-channel endoscopic-assisted posterior lumbar interbody fusion with traditional, posterior lumbar fusion. Bio-Orthopaedic Materials and Clinical Research. 2024; 21(5): 15-20.
16. Yin J, Ma T, Gao G, et al. Early clinical and radiological evaluation of unilateral biportal endoscopic unilateral laminotomy bilateral decompression in degenerative lumbar spinal stenosis: a retrospective study. Journal of neurological surgery. Part A, Central European neurosurgery. 2024. doi:10.1055/a-2281-2135
17. Lu L, Sun S, Li H, et al. Preoperative postural repositioning combined with intraoperative lifting and repositioning assisted by the Mis-TLIF technique in the treatment of isthmic cleft lumbar spondylolisthesis. China Orthopedic Injury. 2024; 37(10): 965-971.
18. Zhao X, Ma H, Geng B, et al. Percutaneous Endoscopic Unilateral Laminotomy and Bilateral Decompression for Lumbar Spinal Stenosis. Orthopaedic Surgery. 2021; 13(2): 641-650. doi: 10.1111/os.12925
19. Chen C, Qian S, Zhao J, et al. Progress of clinical research on endoscopic lumbar interbody fusion with transforaminal approach (Chinese). Chinese Family Medicine. 2024. 22(11): 1924-1928. doi: 10.16766/j.cnki.issn.1674-4152.003766
20. Yu KY. Advances in minimally invasive surgery for degenerative spinal diseases. Chinese Journal of Bone and Joint Surgery. 2021; 14(05): 344-349.
21. Zhu XH. Applied research on 3D printed titanium alloy interbody fusion device for the treatment of lumbar degenerative scoliosis deformity [xxx]. University of Electronic Science and Technology; 2024.
22. Huang HJ, Pang ZC, Feng XF, et al. Effect of intervertebral hybrid bone graft on intervertebral fusion rate after minimally invasive lumbar fusion. Chinese Practical Medicine. 2021; 16(19): 8-11.
23. Cai Y, Liu M, Li Z. Application of allogeneic bone graft materials in spinal fusion. Chinese Tissue Engineering Research. 2023; 27(16): 2571-2579.

24. Shang R, Feng W, Wang J, et al. Clinical effect of spinal endoscopic lumbar interbody fusion technique in the treatment of single-segment lumbar degenerative disease. Chinese Medicine Herald. 2022; 19(33): 79-82.
25. Mehmood A, Shah S, Guo RY, et al. Methyl-CpG-Binding Protein 2 Emerges as a Central Player in Multiple Sclerosis and Neuromyelitis Optica Spectrum Disorders. Cellular and Molecular Neurobiology. 2023; 43(8): 4071-4101. doi: 10.1007/s10571-023-01432-7
26. Zhu J, Hao Y, Ren Z, et al. Preliminary study on unilateral dual channel endoscopic lumbar fusion for the treatment of lumbar degenerative diseases. Chinese Journal of Spine and Spinal Cord. 2021; 31(11): 1026-1033.
27. Jiang C, Huang Y, Zuo H, et al. Early clinical efficacy of unilateral dual channel endoscopic lumbar fusion and minimally invasive transforaminal lumbar fusion for the treatment of single segment lumbar spinal stenosis with instability. Journal of the Chinese Academy of Medical Sciences. 2022; 44(04): 563-569.
28. Song X, Hao Y, Ren Z, et al. Preliminary study on unilateral dual channel endoscopic lumbar fusion for the treatment of grade I lumbar spondylolisthesis. Chinese Journal of Minimally Invasive Surgery. 2022; 22(10): 814-819.
29. Fan Z, Wu X, Guo Z, et al. Comparative study on the efficacy of unilateral dual channel endoscopic lumbar fusion and single channel endoscopic transforaminal lumbar fusion for the treatment of lumbar spinal stenosis with disc herniation. Chinese Journal of Reconstructive Surgery. 2023; 37(09): 1098-1105.
30. Gao L, Gao X, Liu J, et al. A case series study on the treatment of recurrent lumbar disc herniation with unilateral dual channel endoscopic assisted interbody fusion and internal fixation. Journal of Xi'an Jiaotong University (Medical Edition). 2022; 43(05): 720-725.
31. Fu H, Hu Y, Yang D, et al. Comparative study on the efficacy of unilateral dual channel endoscopic decompression and lumbar interbody fusion in the treatment of grade I degenerative lumbar spondylolisthesis. Chinese Journal of Reconstructive Surgery. 2024; 38(02): 169-175.
32. Pourhajrezaei S, Abbas Z, Khalili MA, et al. Bioactive polymers: A comprehensive review on bone grafting biomaterials. International Journal of Biological Macromolecules. 2024; 278: 134615. doi: 10.1016/j.ijbiomac.2024.134615
33. Miron RJ. Optimized bone grafting. Periodontology 2000. 2023; 94(1): 143-160. doi: 10.1111/prd.12517
34. Brachet A, Bełżek A, Furtak D, et al. Application of 3D Printing in Bone Grafts. Cells. 2023; 12(6): 859. doi: 10.3390/cells12060859
35. Zhao D, Wang C, Han Q, et al. Research Status and Progress of 3D Printing Medical Titanium Alloy Implants. China Medical Device Information. 2017; 23(03): 1-5,15.