

Comparison of Early Outcomes between Percutaneous Endoscopic and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Spondylolisthesis

Hao Zhang

The Affiliated Hospital of Qingdao University

Chuanli Zhou

The Affiliated Hospital of Qingdao University

Chao Wang

The Affiliated Hospital of Qingdao University

Kai Zhu

The Affiliated Hospital of Guizhou Medical University

Qihao Tu

The Affiliated Hospital of Qingdao University

Meng Kong

The Affiliated Hospital of Qingdao University

Chong Zhao

The Affiliated Hospital of Qingdao University

Xuexiao Ma (✉ maxuexiaospinal@163.com)

Affiliated Hospital of Qingdao University <https://orcid.org/0000-0002-0967-6424>

Research article

Keywords: Endo-TLIF, MIS-TLIF, lumbar spondylolisthesis

Posted Date: October 14th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-89182/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

With the rapid development of less-invasive techniques, the percutaneous endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) as a novel minimal surgical technique for treating lumbar spondylolisthesis in recent years. To compare the preliminary efficacy of Endo-TLIF with that of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) for the treatment of lumbar spondylolisthesis.

Methods

Between May and August 2019, 62 patients with single-segment lumbar spondylolisthesis treated by a single surgeon were enrolled in this clinical study: there were 32 patients in the Endo-TLIF group and 30 patients in the MIS-TLIF group. Perioperative parameters, including operative time, estimated blood loss (EBL), interoperative fluoroscopy time, ambulation time and operative complications, were recorded. At preoperatively, 1 week, 3 months, 6 months and 12 months postoperatively, the results of clinical metrics such as the Visual Analog Scale (VAS) for back pain, the Oswestry Disability Index (ODI) and the Japanese Orthopaedic Association (JOA) score were obtained and used to compare early outcomes between the two groups. Postoperative fusion rates were assessed by CT scans 12 months after surgery.

Results

No significant differences were found in the demographic data, including sex, age, body mass index (BMI), segment distribution and spondylolisthesis severity, between the two groups. Compared with MIS-TLIF group, Endo-TLIF group had a similar operative time (202.6 ± 31.4 minutes), less intraoperative blood loss (73.0 ± 26.0 ml) and a shorter ambulation time (1.6 ± 0.6 days) but had a longer duration of X-ray radiation (46.3 ± 5.1 seconds). The postoperative VAS scores for back pain as well as the ODI and JOA scores were improved compared with the preoperative scores in the two groups, but the Endo-TLIF group showed more significant improvement in the early follow-up. There were no significant differences in terms of the interbody fusion rate between the two groups. However, no obvious postoperative complications were observed in the study.

Conclusion

Endo-TLIF technique shows relatively better outcomes compared with MIS-TLIF in terms of an early curative effect, especially one week and six months postoperatively.

Background

Lumbar spondylolisthesis is defined as a forward slippage of a lumbar vertebra relative to the next vertebral body and resulting in instability of the segment[1, 2]. The most common types include degenerative and isthmic lumbar spondylolisthesis. Degenerative spondylolisthesis is one of the most

common degenerative spinal disorder in the aging population, and often associated with lumbar canal stenosis[3, 4]. And, it is also a frequent cause of low back pain, and it results from a narrowing of the disc space or nerve root canal[2]. Bhalla pointed out that the chief goals of surgical treatment include neurologic decompression and stabilization of the vertebral segments with instrumented fusion[5]. Posterior lumbar interbody fusion (PLIF) is regarded as most common surgery for degenerative lumbar disease such as degenerative spondylolisthesis and lumbar spinal stenosis[6]. Although open surgery can have good effects, it may damage the paraspinal muscles, result in postoperative pain, prolong hospital stays, protract rehabilitation programs and increase the financial burden to patients. Fan et al. reported extensive stripping of muscles, ligament resection, destroy the architecture of the spinal posterior column may result in spinal instability and failed back surgery syndrome (FBSS)[7]. These drawbacks of standard posterior lumbar interbody fusion have prompted the development of less-invasive techniques[8–11]. Furthermore, with the improvements in surgical instruments and the increase in patients' demands for quality of life, minimally invasive surgery has been accepted by an increasing number of physicians and patients. Kai-Michael et al[12] pointed out that numerous minimally invasive techniques have been applied for spinal surgery since a novel tubular retractor system was introduced by Foley in 1997. In recent years, a variety of less-invasive procedures that can minimally disrupt normal structures without compromising effectiveness have been applied in the field of spinal surgery, such as minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF), anterior lumbar interbody fusion (ALIF), extreme lateral lumbar interbody fusion (XLIF) and oblique lumbar interbody fusion (OLIF), each having its own benefits and drawbacks[13, 14].

Harms et al.[15] first reported transforaminal lumbar interbody fusion (TLIF) technique, which can effectively avoid muscle and nerve root traction injury, in 1982. In 2002, Foley[16] reported that the MIS-TLIF technique, which was derived from TLIF and is performed with a tubular retractor, could effectively preserve back muscles and reduce postoperative complications. In recent years, it has been widely used in the treatment of a variety of lumbar degenerative diseases, with satisfactory outcomes obtained[17]. Many studies have shown that advanced MIS-TLIF is associated with less blood loss and a shorter recovery time than conventional open surgery, but laminotomy, facetectomy and flavum dissection are necessary in order to achieve interbody fusion with the use of cages. Meanwhile, this technique still questioned by its limited workspace and the field of vision of this surgical procedure, steep learning curve, and may higher incidence of complications[18].

Recently, the percutaneous endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) technique was reported to address a variety of spinal disorders by using endoscopic and expandable cages through Kambin's triangle[19, 20]. Endo-TLIF technique was derived from the percutaneous endoscopic lumbar discectomy (PELD) technique and combined endoscopic visualization, expandable cage technology, and interbody fusion technique[21]. As reported, the Endo-TLIF technique can achieve not only bilateral direct decompression, interbody cage insertion and pedicle implantation but also less dissection of normal structures. In other words, the muscle, soft tissue and nerve roots can be significantly protected because of the access to procedures and the direct visualization under endoscopy. In 2020, AO et al.[22] reported that their study showed that, compared with MIS-TLIF, their percutaneous endoscopic transforaminal

lumbar interbody fusion technique has advantages of less surgical trauma, less hidden blood loss, less postoperative low-back pain, and faster recovery. Although both their and our techniques share the label of percutaneous endoscopic transforaminal lumbar interbody fusion technique, they differ in several aspects. The difference not only in the methods of screw implantation, working channel system, surgical procedures and details but also in interbody implant cage. In recent years, research on the Endo-TLIF technique has become a hot topic, and among them, a great many spine surgeons put more attention into the clinical application of the technology, which is an important field.

There are a limited number of studies that have evaluated the use of the Endo-TLIF technique for the treatment of lumbar spondylolisthesis and compared early clinical outcomes with those of other minimally invasive lumbar fusion surgeries. So that, surgeons lack references related to percutaneous endoscopic lumbar interbody fusion technique and clinical experience in evaluating preliminary clinical outcomes. Thus, the aims of this study were as follow: (i) demonstrate the surgical procedures, technique, advantages and drawbacks of Endo-TLIF and MIS-TLIF; (ii) evaluate and compare the early clinical efficacies of two minimally invasive techniques for single-segment lumbar spondylolisthesis; (iii) provide spine surgeons and patients with accurate early outcome of Endo-TLIF and MIS-TLIF and relevant theoretical basis for the choice of operation method.

Methods

Method approach to clinical study, the Endo-TLIF group compared with the MIS-TLIF group. In total, 62 patients were enrolled in the study between May and August 2019 according to the screening criteria. The procedures were approved by the ethics committee of the Affiliated Hospital of Qingdao University.

The inclusion criteria were defined as follows: (i) Patients over 18 years old; (ii) Patients who were diagnosed with degenerative or isthmic spondylolisthesis (Grade I/II) with or without resultant stenosis at one lumbar level; (iii) Patients who were diagnosed with single segment lumbar instability; (iv) Patients who had neural symptoms (including low back pain, sciatica and extremity symptoms); (v) Patients whose symptoms were not alleviated after 6 months or more of conservative therapy.

The exclusion criteria were defined as follows: (i) Patients with serious systemic diseases or patients who could not withstand surgical treatment; (ii) Patients who had undergone previous lumbar fusion surgery or patients who needed treatment for more than one level; (iii) Patients who were mentally incompetent; (iv) Patients who had trauma, arachnoiditis, active infection (local or systemic) or spinal metastasis.

All diagnoses were based on clinical symptoms and neuroradiological imaging manifestations, especially those of extension and flexion lateral radiograph, computerized tomography (CT) and magnetic resonance imaging (MRI) scans. Patients enrolled in the experiment were divided into two groups: the Endo-TLIF group and the MIS-TLIF group. All patients underwent surgery, received general anesthesia in the prone position and were followed up for a period of 12 months. None was lost to follow up in the two groups.

Endo-TLIF Technique

Following induction of general anesthesia, the patients were positioned prone on a radiolucent table. Spinal cord monitoring was performed during the procedure to prevent unexpected nerve injury. Compared with other Endo-LIF, the instruments called Endo Surgi-Plus® and Endo-TLIF system were designed and manufactured by Unin-tech company from China, and all the procedures were visualized under the endoscopy. The entry point for endoscopic working channel and the insertion of pedicle screws were marked on the skin via fluoroscopy. Two or four longitudinal incisions with the length from 1 to 1.5 cm approximately 4–6 cm from the spinous process was made on the side and at the level of pathology based on the entry point. Blunt guiding rod was inserted along the guiding wire of inferior percutaneous pedicle screw and put on the surface of the zygapophyseal joint, followed by working channel. The appropriate position for insertion of the working channel was confirmed with anteroposterior and lateral X-ray views (Fig. 1).

Foraminoplasty and laminectomy were achieved by the removal of part of the superior and inferior articular process with full-size reamers for 4–8 times. A satisfactory foraminoplasty and laminectomy was obtained through multiple reamers cutting and lamina forceps according to preoperative plan for decompression. Caudal, cephalad, lateral edge of ligament flavum were visible clearly and removed with rongeurs. By turning the working channel from a ventral to dorsal position, the nerve root and dural sac were protected behind the sharp bevel of the working cannula. Next, discectomy and nerve root decompression were performed using the Endo Surgi-Plus® and Endo-TLIF system under endoscopic visualization (Fig. 1). Bilateral discectomy and nerve root decompression should be performed for patients with neurological symptoms of both lower limbs through the Endo-TLIF technique.

All the procedures of Discectomy and endplate preparation were finished under endoscopy by using osteotomes, blue forceps, inside and outside reamer, chisel, scraper and flexible scraper. Bone graft bed was made into fan shaped, and as good as that in open posterior lumbar interbody fusion (PLIF) surgery, trial cages were implanted with increasing sizes under fluoroscopic control (Fig. 1). Based on the results of the trial cage, a suite of expandable interbody cages filled with decompressed skeletal particles was selected and subsequently placed into the disc space through the working tube. The cages were adjusted to a satisfactory position according to intraoperative fluoroscopy; then, the cages were expanded to increase the rear height by 2 mm to make full contact with the endplate. The cage was expanded through the special access cannula, then, sufficient bony grafts was placed in the expanded cage through a hollow tube (Fig. 2).

Before removing the working channel and prior to endoscopy, the cage position and decompression effect of the nerve root were confirmed again. Four guide wires were placed through cannulated needles that were inserted into the pedicle based on the bilateral pedicle projection. Pedicle screw holes were tapped, and screws and rods were inserted percutaneously (Fig. 2).

MIS-TLIF technique

Under the guidance of the C-arm X-ray machine, the surgical level was located, and the skin incision was made on the side and at the level of pathology. The muscle (multifidus and longissimus muscles) was bluntly separated from dorsal to ventral, and the quadrant system was placed on the symptomatic side via the muscular gaps. Unilateral laminectomy, facetectomy, partial ligament flavum resection, nerve root decompression, excision of the intervertebral disc and a sizeable rigid PEEK cage placement were performed based on the quadrant dilator. The process of pedicle screw and rod placement was the same as that used for Endo-TLIF.

Clinical Outcomes

All data were collected after the acquisition of written informed consent from the patients. The demographic data collected included sex, age, body mass index (BMI), segment distribution and spondylolisthesis severity. Patients were assessed for perioperative factors such as operative time, estimated blood loss (EBL), intraoperative fluoroscopy time, ambulation time and operative complications. The results of clinical metrics such as the Visual Analog Scale (VAS) for back pain, the Oswestry Disability Index (ODI) and the Japanese Orthopaedic Association (JOA) score were obtained and used to compare the early outcomes between the two groups on preoperative day 1 and on postoperative week 1 as well as months 3, 6 or 12. Postoperative fusion rates were assessed by CT scan 6 to 12 months after surgery. Continuous bone trabecular bridging between intervertebral bodies was considered as the standard of spinal intervertebral fusion[23].

Visual Analogue Scale (VAS)

The VAS is a continuous scale comprised of a 10 cm horizontal line, usually used to measure the quantification of pain. The scale of pain intensity is most commonly divided as follow: no pain (0–2), mild pain (3–5), moderate pain (6–8), and severe pain (8–10).

Oswestry disability index (ODI)

Oswestry disability index (ODI) is a principal condition-specific outcome measures used in the management of spinal disorders, and to assess patient progress in routine clinical practice. If all 10 sections are completed the score is calculated as follows: $\frac{\text{total scored}}{\text{total possible score}} \times 100$. If one section is missed (or not applicable) the score is calculated: $\left(\frac{\text{total score}}{5 \times \text{number of questions answered}} \right) \times 100\%$. 0%-20% is considered mild dysfunction, 21%-40% is moderate dysfunction, 41%-60% is severe dysfunction, and 61%-80% is considered as disability. For cases with score of 81%-100%, either long-term bedridden, or exaggerating the impact of pain on their life.

Japanese Orthopaedic Association (JOA) score

The JOA scoring is one of the most frequently used clinical outcome measures to reflect the improvement of lumbar function before and after treatment. The JOA total score is 29 points and the lowest is 0 points. A higher score indicates more complete the lumbar function.

Data analysis

Statistical analysis was performed using the SPSS 22.0 statistical software package (SPSS Inc., Chicago, IL, USA). The continuous data from the Endo-TLIF and MIS-TLIF groups were assessed with t-tests. Categorical variables were analyzed with the χ^2 test. A P-value < 0.05 was considered statistically significant.

Results

Perioperative Parameters

The mean age of the 32 (51.6%) patients in the Endo-TLIF group was 53.1 years old (53.1 ± 16), and there were 12 males and 20 females. The mean age of the 30 (48.4%) patients in the MIS-TLIF group was 55.7 years old (55.7 ± 14.2), and there were 14 males and 16 females. No significant differences were found in the demographic data of all patients in the two groups. Further details were listed Table 1. Compared with the MIS-TLIF group, the Endo-TLIF group had a lower estimated intraoperative blood loss (73.0 ± 26.4 ml), a shorter ambulation time (1.6 ± 0.6 days) and a higher intraoperative fluoroscopy time (46.3 ± 5.1 seconds). In our study, MIS-TLIF need at least 7 times X-rays but Endo-TLIF requires at least 15 times X-rays. A longer mean operation time was observed in the Endo-TLIF group (202.6 ± 31.4 minutes) than in the MIS-TLIF group (192.1 ± 18.9 minutes), but there were no statistically significant differences between the two groups. The further perioperative indicators are shown in Table 2.

Table 1
Demographic Data

Characteristic	Endo-TLIF Group (n = 32)	MIS-TLIF Group (n = 30)	P-value
No. of cases	32	30	
Age(yrs)	53.1(± 12.8)	55.7(± 14.2)	0.45
Gender(M/F)	12/20	14/16	
Body mass index(kg/m2)	25.5(± 1.6)	24.9(± 1.8)	0.17
Operated level			0.53
L3-4	3	1	
L4-5	28	27	
L5-S1	1	2	
Spondylolisthesis Severity			0.39
Grade I	22	24	
Grade II	10	6	
Spondylolisthesis Type			0.21
Degenerative	19	12	
Isthmic	14	18	

Table 2
Perioperative Parameters

	Endo-TLIF Group	MIS-TLIF Group	P-value
Operative time (minute)	202.6(± 31.4)	192.1(± 18.9)	0.1189
Estimated blood loss (EBL ml)	73.0(± 26.4)	129.0(± 31.7)	< 0.0001
Intraoperative fluoroscopy time (second)	46.3(± 5.1)	32.2(± 3.9)	< 0.0001
Ambulation time (day)	1.6(± 0.6)	2.3(± 0.8)	0.0002
Interbody fusion rate	30/32(93.8%)	30/30(100%)	0.4923

Table 3
Preoperative, follow-up VAS, ODI, and JOA scores

	Endo-TLIF Group	MIS-TLIF Group	P-value
Back pain VAS scores			
Peroperation	6.84(± 1.65)	6.52(± 1.27)	0.3978
1 week postoperation	5.10(± 1.14)	6.33(± 1.38)	0.0003 ***
3 months postoperation	2.21(± 0.74)	2.96(± 1.63)	0.0217 *
6 months postoperation	1.77(± 0.92)	2.10(± 1.06)	0.1947
12 months postoperation	1.56(± 1.26)	1.68(± 0.89)	0.6684
Leg pain VAS scores			
Peroperation	7.38 ± 2.61	7.88 ± 2.54	0.4481
1 week postoperation	5.32 ± 2.20	4.74 ± 1.75	0.2572
3 months postoperation	2.64 ± 1.61	2.58 ± 1.80	0.8903
6 months postoperation	1.65 ± 0.87	2.10 ± 0.96	0.0576
12 months postoperation	0.83 ± 1.12	0.79 ± 0.54	0.860
ODI scores			
Peroperation	40.52(± 8.70)	42.16(± 8.41)	0.4539
1 week postoperation	35.32(± 5.86)	38.86(± 7.21)	0.0375 *
3 months postoperation	21.83(± 6.37)	30.21(± 8.85)	< 0.001****
6 months postoperation	20.24(± 6.95)	23.47(± 5.48)	0.0475 *
12 months postoperation	16.77(± 5.26)	17.28(± 5.73)	0.7161
JOA			
Peroperation	13.74(± 2.35)	14.58(± 2.09)	0.1432
1 week postoperation	19.36(± 1.53)	17.11(± 2.78)	0.0002 ***
3 months postoperation	23.27(± 1.73)	22.54(± 1.57)	0.0877
6 months postoperation	25.61(± 1.28)	24.85(± 1.62)	0.0441 *

Functional Evaluation

Both groups showed a significant reduction in the VAS scores for back pain and in the ODI score, but the Endo-TLIF group showed a better curative effect at the 6-month follow-up. At more than 6 months postoperatively, both groups showed continuous improvement, but there were no significant differences

between the two groups. Leg pain VAS scores were similar between the two groups with no significant differences in the follow-up period. JOA scores were used to assess neurologic function, and the further results are shown in Fig. 3.

Interbody Fusion

In 2 cases in the Endo-TLIF group, continuous bone trabecular bridging could not be identified based on the CT scan at the 12-month follow-up, and the remaining 60 cases in the two groups were regarded as interbody fusion (Fig. 4). However, it must be noted that there were no significant differences in the interbody fusion rates between the two groups.

Complications

There were no cases of severe complications, such as postoperative infections, dura mater tears or nerve root injuries. But one case of Endo-TLIF group happened that the shorter rod came off from the screw 7 week later after the surgery and was revised under local anesthesia to change a longer rod.

Discussion

Theoretical Basis and Advantages of Endo-TLIF

Endo-TLIF technique was derived from the PELD technique and can be combined with the interbody fusion technique. The present study showed that Endo-TLIF offered many advantages over MIS-TLIF for the treatment of LSS. In our study, the MIS-TLIF technique requires 4–5 cm lengthy skin incision approximately. Although the Wiltse approach with the use of a quadrant channel can reduce the need for muscular stripping, it still requires partial laminotomy to achieve decompression and fusion[18]. Because of the application of endoscopy and progressive tissue dilation, the Endo-TLIF technique is performed with a 1-1.5 cm-length skin incision and entirely preserves the function of paraspinal muscles. Furthermore, because of the smaller tube used, the technique requires a more accurate angle for working channel placement. As has been reported, the limited amount of muscle dissection and innervation damage are principle factors that can lessen the incidence of low back pain and shorten the recovery time[7]. In the Endo-TLIF group, the mean amount of blood loss was 73.0 (\pm 26.4) ml without postoperative drainage, and the patients were ambulatory within 12 hours. Compared with MIS-TLIF group, continuous irrigation of normal saline and certain water pressure during the operation may be one of the main factors for reducing blood loss.

Conventional fusion is still the widely accepted standard for managing lumbar degeneration disorders that required the maintenance of spinal stabilization. The distinguishing factor of the Endo-TLIF technique is the endoscopy-based transforaminal posterolateral approach that permits the use of an expandable fusion cage placed in the disk space through Kambin's triangle with limited removal of bone structure[24]. Nerve root injury is one of the most serious complications of spinal surgery, so to protect

nerve roots, we must pay great attention before each step in the procedure that may result in damage. Foraminoplasty is a necessary step for enlarging the foramen in order to provide sufficient space for subsequent procedures and eliminate exiting root injury[19]. Similar to the PELD technique, the nerve root can be protected by a working tube with a beveled tip from trepan cutting and cage implantation. There were no cases of exiting nerve root injury in the study. Endplate preparation and expandable cage placement under direct endoscopic visualization provides an effective advantage for the protection of nerves and the dural sac.

The application of expandable cages is also one of the advantages of the Endo-TLIF technique. Compared with a rigid PEEK cage, this cage requires less excision of bony structures and a smaller size in order to obtain a satisfactory result and to avoid the excessive pulling of nerve roots[25]. Expandable cages are convenient for implantation, and they provide sufficiently high interbody restoration during lumbar spine surgery. Spinal leg pain may result from disc and foraminal collapse, which results in compression of the exiting nerve root. In such circumstances, expandable cage implantation can restore intervertebral height to achieve indirect neural decompression and additional foraminal expansion[26]. The Varian® cage (Medyssey, Korea) that we used in Endo-TLIF procedure allowed adjustment of the cage's position once expansion was implemented before the bone graft was placed. In addition, the surface of the expandable cage provides stability and decent bone integration with the help of a bone graft within the cage. Endplate preparation is a vital step for achieving satisfactory fusion. In our study, interbody fusion was obtained in 60 patients and was confirmed with postoperative CT scans, no cage subsidence was observed in two groups. The damage to the endplate in the process of cage implantation might have been the main cause of cage subsidence, so that, satisfactory endplate preparation and careful cage implantation were performed in the process of surgery. In addition, percutaneous pedicle screw fixation is necessary in Endo-TLIF, especially for patients who have broken endplates or osteoporosis[27].

Drawbacks of Endo-TLIF

Endo-TLIF technique offers many advantages, such as limited invasiveness, limited intraoperative blood loss, a short recovery time and no need for postoperative drainage. Despite the many benefits mentioned above, there are some limitations that should be given attention. The locations of the working tube, expandable cage and pedicle screws need to be determined with X-ray during the operation, thus, patients and doctors are exposed to high doses of radiation. It is undeniable that the Endo-TLIF technique still requires a steep learning curve while requiring a thorough understanding of foraminal anatomy and rich endoscopic experience.

Limitation of Study

Some limitations of the study must be noted. First, the number of patients in the two groups was relatively small. Second, all patients in the study were only followed for 1 year, so a larger sample with a longer follow-up time is needed to make definitive clinical conclusions. Finally, the height of the iliac crest had some influence on patient selection.

Conclusions

In present study, Endo-TLIF technique has shown great advantages in terms of the early curative effect in patients. As a result of the study, the Endo-TLIF technique seems to be a suitable choice for patients with lumbar spondylolisthesis due to its advantages of being minimally invasive and the fact that it can even be performed under local anesthesia. The use of the Endo-TLIF technique is increasing, and in the near future, it will become a prominent part of spinal surgery.

Abbreviations

Endo-TLIF

percutaneous endoscopic transforaminal lumbar interbody fusion;

MIS-TLIF

minimally invasive transforaminal lumbar interbody fusion;

EBL

estimated blood loss;

VAS

Visual Analog Scale;

ODI

Oswestry Disability;

JOA

Japanese Orthopaedic Association;

BMI

body mass index;

PLIF

Posterior lumbar interbody fusion;

CT

computerized tomography;

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Ethics Committee of Affiliated Hospital of Qingdao University. A written informed consent was taken from each patient.

Consent for publication

Not applicable.

Availability of data and materials

The data supporting the findings of the current study are available within the article.

Competing interests

The author reports no conflicts of interest in this work

Funding

This work was supported by grants from the National Natural Science Foundation of China (81672200, 81871804) and National Key Research and Development Project (CN) (2019YFC0121400). The funding bodies played no roles in the study design, writing of the manuscript, or decision to submit the manuscript for publication.

Authors' contributions

H.Z., CL.Z and XX.M. designed the study. H.Z., C.W., and QH.T. collected the data. H.Z., CL.Z., C.Z., M.K., and K.Z. conducted the analyses and interpreted the data. H.Z. and CL.Z. drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgments

None

References

1. De Kunder SL, Van Kuijk SMJ, Rijkers K, Caelers I, Van Hemert WLW, De Bie RA, Van Santbrink H. Transforaminal lumbar interbody fusion (TLIF) versus posterior lumbar interbody fusion (PLIF) in lumbar spondylolisthesis: a systematic review and meta-analysis. *Spine J.* 2017;17(11):1712–21. <https://doi.org/10.1016/j.spinee.2017.06.018>.
2. Bydon M, Alvi MA, Goyal A. Degenerative Lumbar Spondylolisthesis: Definition, Natural History, Conservative Management, and Surgical Treatment. *Neurosurg Clin N Am.* 2019;30(3):299–304. <https://doi.org/10.1016/j.nec.2019.02.003>.
3. Koreckij TD, Fischgrund JS. Degenerative Spondylolisthesis. *J Spinal Disord Tech.* 2015;28(7):236–41. <https://doi.org/10.1097/bsd.0000000000000298>.
4. Ferrero E, Guigui P. Current trends in the management of degenerative lumbar spondylolisthesis. *EFORT Open Rev.* 2018;3(5):192–9. <https://doi.org/10.1302/2058-5241.3.170050>.
5. Bhalla A, Bono CM. Isthmic Lumbar Spondylolisthesis. *Neurosurg Clin N Am.* 2019;30(3):283–90. <https://doi.org/10.1016/j.nec.2019.02.001>.
6. Li D, Hai Y, Meng X, Yang J, Yin P. Topping-off surgery vs posterior lumbar interbody fusion for degenerative lumbar disease: a comparative study of clinical efficacy and adjacent segment degeneration. *J Orthop Surg Res.* 2019;14(1):197. <https://doi.org/10.1186/s13018-019-1245-3>.

7. Fan SW, Hu ZJ, Fang XQ, Zhao FD, Huang Y, Yu HJ. Comparison of paraspinal muscle injury in one-level lumbar posterior inter-body fusion: modified minimally invasive and traditional open approaches. *Orthop Surg*. 2010;2(3):194–200. <https://doi.org/10.1111/j.1757-7861.2010.00086.x>.
8. Weber BR, Grob D, Dvorak J, Muntener M. Posterior surgical approach to the lumbar spine and its effect on the multifidus muscle. *Spine*. 1997;22(15):1765–72. <https://doi.org/10.1097/00007632-199708010-00017>.
9. Elias WJ, Simmons NE, Kaptain GJ, Chadduck JB, Whitehill R. Complications of posterior lumbar interbody fusion when using a titanium threaded cage device. *J Neurosurg*. 2000;93(1 Suppl):45–52. <https://doi.org/10.3171/spi.2000.93.1.0045>.
10. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. *Spine*. 1996;21(8):941–4. <https://doi.org/10.1097/00007632-199604150-00007>.
11. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR. Perioperative outcomes and adverse events of minimally invasive versus open posterior lumbar fusion: meta-analysis and systematic review. *J Neurosurg Spine*. 2016;24(3):416–27. <https://doi.org/10.3171/2015.2.Spine14973>.
12. Scheufler KM, Dohmen H, Vougioukas VI. Percutaneous transforaminal lumbar interbody fusion for the treatment of degenerative lumbar instability. *Neurosurgery*. 2007;60(4 Suppl 2):203–12. <https://doi.org/10.1227/01.Neu.0000255388.03088.B7>. discussion 12 – 3.
13. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. *Spine*. 2003;28(15 Suppl):S26–35. <https://doi.org/10.1097/01.Brs.0000076895.52418.5e>.
14. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. *J Spine Surg*. 2015;1(1):2–18. <https://doi.org/10.3978/j.issn.2414-469X.2015.10.05>.
15. Harms J, Rolinger H. A one-stager procedure in operative treatment of spondylolistheses: dorsal traction-reposition and anterior fusion. *Z Orthop Ihre Grenzgeb*. 1982;120(3):343–7. <https://doi.org/10.1055/s-2008-1051624>.
16. Foley KT, Lefkowitz MA. Advances in minimally invasive spine surgery. *Clin Neurosurg*. 2002;49:499–517.
17. Wang HW, Hu YC, Wu ZY, Wu HR, Wu CF, Zhang LS, Xu WK, Fan HL, Cai JS, Ma JQ. Minimally Invasive Transforaminal Lumbar Interbody Fusion and Unilateral Fixation for Degenerative Lumbar Disease. *Orthop Surg*. 2017;9(3):277–83. <https://doi.org/10.1111/os.12345>.
18. Wu AM, Hu ZC, Li XB, Feng ZH, Chen D, Xu H, Huang QS, Lin Y, Wang XY, Zhang K, et al. Comparison of minimally invasive and open transforaminal lumbar interbody fusion in the treatment of single segmental lumbar spondylolisthesis: minimum two-year follow up. *Ann Transl Med*. 2018;6(6):105. <https://doi.org/10.21037/atm.2018.02.11>.
19. Wu J, Liu H, Ao S, Zheng W, Li C, Li H, Pan Y, Zhang C, Zhou Y. Percutaneous Endoscopic Lumbar Interbody Fusion: Technical Note and Preliminary Clinical Experience with 2-Year Follow-Up. *Biomed Res Int*. 2018;2018:5806037. <https://doi.org/10.1155/2018/5806037>.

20. Yang J, Liu C, Hai Y, Yin P, Zhou L, Zhang Y, Pan A, Zhang Y, Zhang L, Ding Y, et al. Percutaneous Endoscopic Transforaminal Lumbar Interbody Fusion for the Treatment of Lumbar Spinal Stenosis: Preliminary Report of Seven Cases with 12-Month Follow-Up. *Biomed Res Int*. 2019;20193091459. <https://doi.org/10.1155/2019/3091459>.
21. Syed H, Voyadzis JM. True Percutaneous Transforaminal Lumbar Interbody Fusion: Case Illustrations, Surgical Technique, and Limitations. *J Neurol Surg A Cent Eur Neurosurg*. 2016;77(4):344–53. <https://doi.org/10.1055/s-0035-1558821>.
22. Ao S, Zheng W, Wu J, Tang Y, Zhang C, Zhou Y, Li C. Comparison of Preliminary clinical outcomes between percutaneous endoscopic and minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative diseases in a tertiary hospital: Is percutaneous endoscopic procedure superior to MIS-TLIF? A prospective cohort study. *International journal of surgery (London England)*. 2020;76136–43. <https://doi.org/10.1016/j.ijssu.2020.02.043>.
23. Rothman SL, Glenn WV. Jr. CT evaluation of interbody fusion. *Clin Orthop Relat Res*. 1985(193):47–56.
24. Morgenstern R, Morgenstern C. Percutaneous Transforaminal Lumbar Interbody Fusion (pTLIF) with a Posterolateral Approach for the Treatment of Denegenerative Disk Disease: Feasibility and Preliminary Results. *Int J Spine Surg*. 2015;941. <https://doi.org/10.14444/2041>.
25. Lee SH, Erken HY, Bae J. Percutaneous Transforaminal Endoscopic Lumbar Interbody Fusion: Clinical and Radiological Results of Mean 46-Month Follow-Up. *Biomed Res Int*. 2017;20173731983. <https://doi.org/10.1155/2017/3731983>.
26. Shen J. Fully Endoscopic Lumbar Laminectomy and Transforaminal Lumbar Interbody Fusion Under Local Anesthesia with Conscious Sedation: A Case Series. *World Neurosurg* 2019;127e745-e50. <https://doi.org/10.1016/j.wneu.2019.03.257>.
27. Osman SG. Endoscopic transforaminal decompression, interbody fusion, and percutaneous pedicle screw implantation of the lumbar spine: A case series report. *Int J Spine Surg*. 2012;6157–66. <https://doi.org/10.1016/j.ijssp.2012.04.001>.

Figures

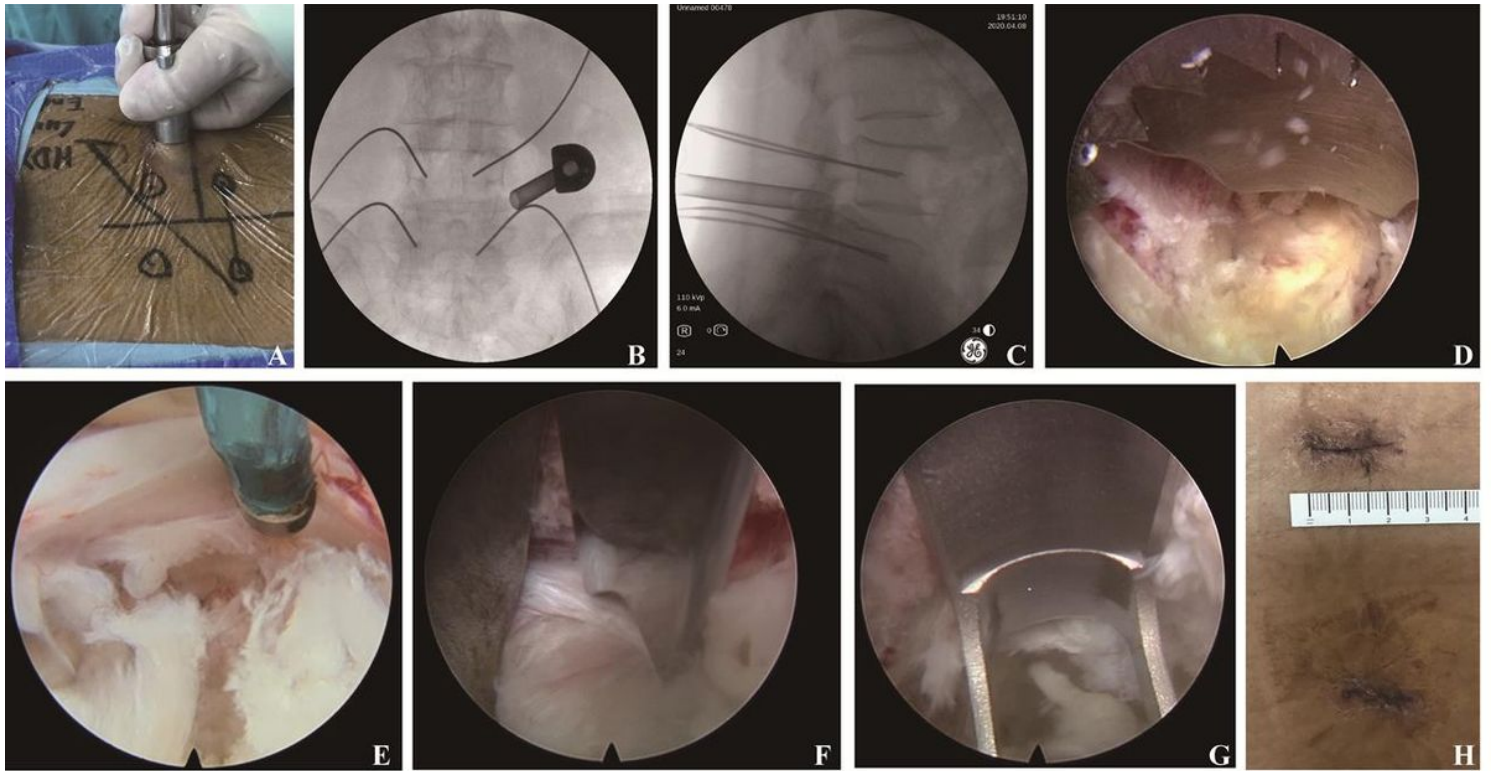


Figure 1

(A) The marks of entry points on the skin. (B) (C) The position for insertion of working channel in anteroposterior and lateral X-ray views. (D) Foraminoplasty under endoscopic views. (E) (F) Neurological decompression and discectomy by osteotome under endoscopic views. (G) Endplate preparation by using reamers under endoscopic views. (H) 2 cm-length postoperative skin incision.

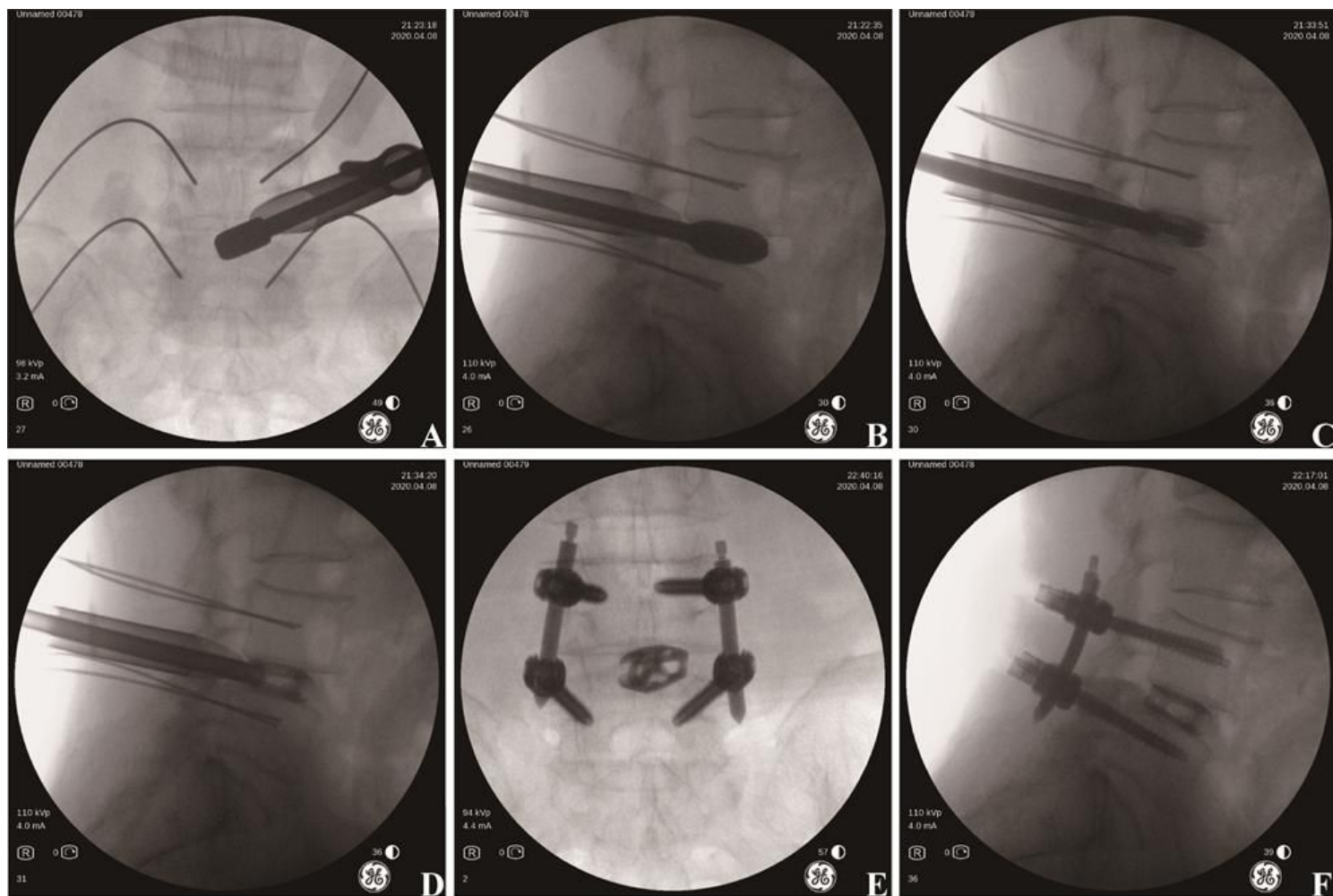


Figure 2

(A) (B) Identification of the trial cage position by anteroposterior and lateral X-ray views. (C) Unexpanded cage in lateral X-ray views. (D) Adequately expanded cage in lateral X-ray views. (E) (F) The position of expanded cage and percutaneous pedicle screws in anteroposterior and lateral X-ray views.

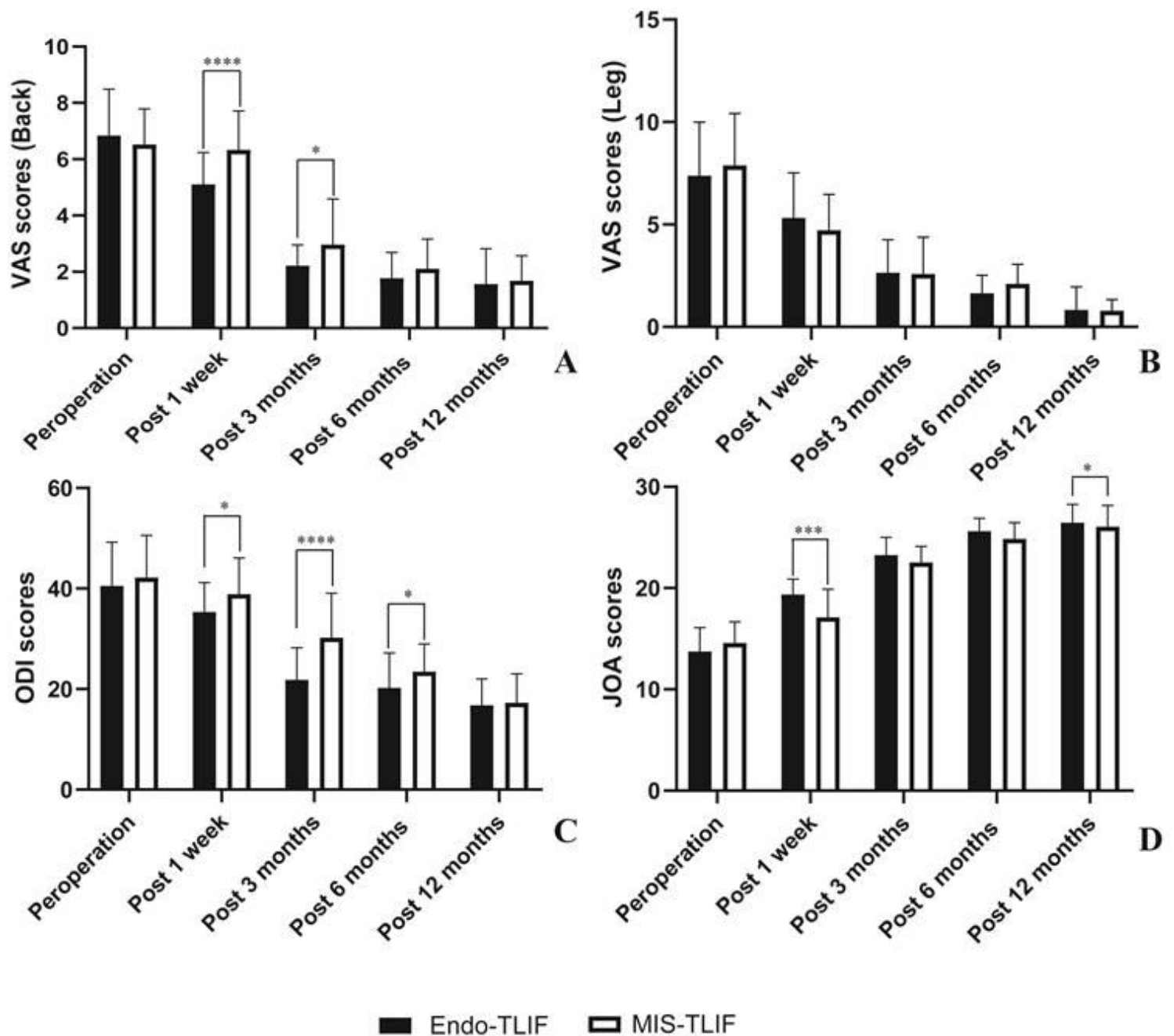


Figure 3

Comparison of (A) Back pain VAS scores, (B) Leg pain VAS scores, (C) ODI scores and (D) JOA scores between the Endo-TLIF and MIS-TLIF groups.

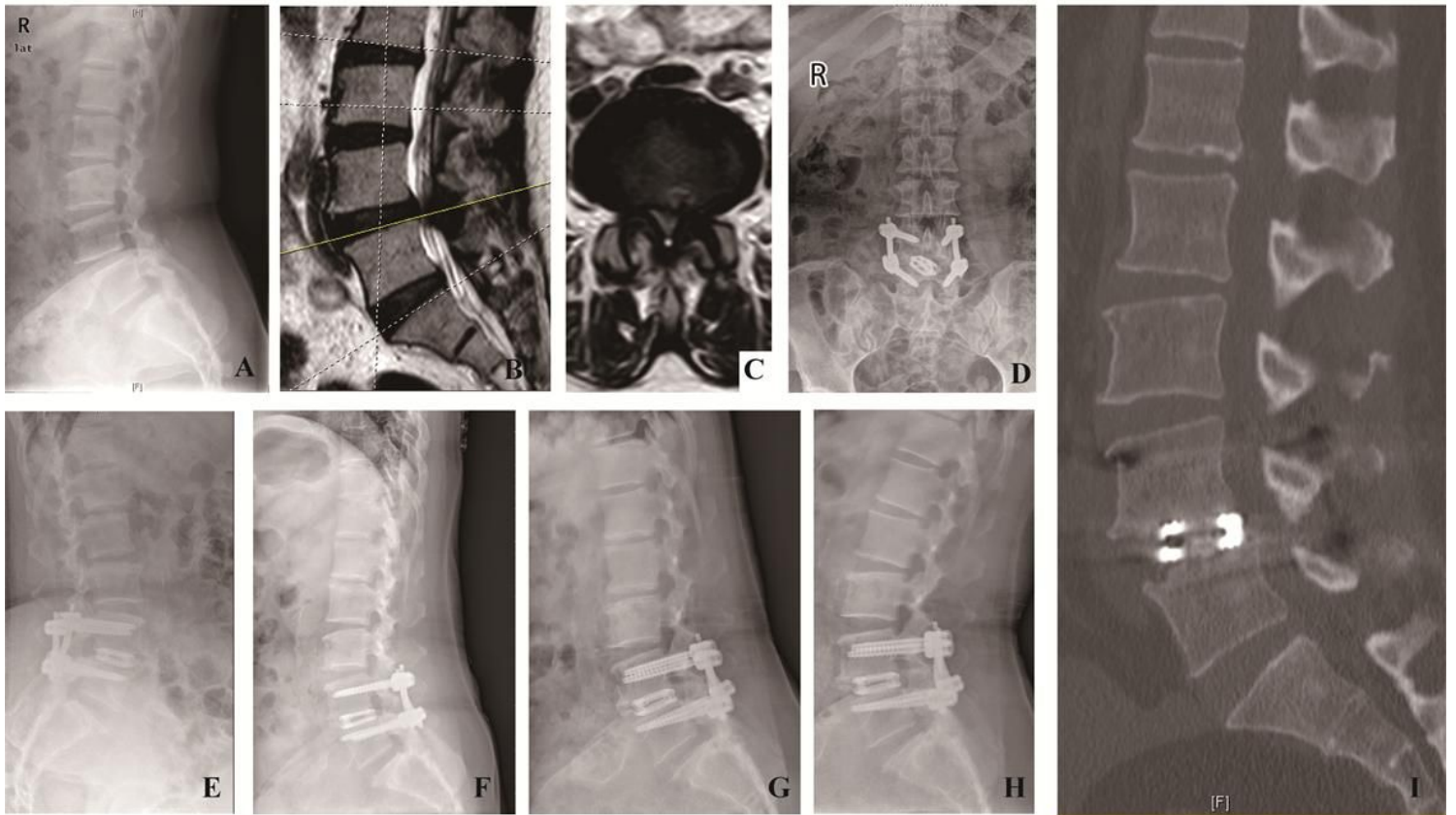


Figure 4

(A) Preoperative lateral radiograph showed the spondylolisthesis (L4/5). (B), (C) Preoperative MRI showed the lumbar spondylolisthesis and resultant stenosis (L4/5). (D), (E) anteroposterior and lateral radiograph at 3 months postoperative. (F) Lateral radiograph at 6 months postoperative. (G), (H) Extension and flexion lateral radiograph at 12 months follow-up. (I) CT scan image showed continuous bone trabecular bridging between intervertebral bodies at 6 months follow-up.