Original Article

Minimally invasive transforaminal lumbar interbody fusion: Technical tips, learning curve, short-term clinical outcome, and brief review

ABSTRACT

Background: Current trends in spine surgeries have shifted to minimally invasive procedures. Minimally invasive approaches are getting more popular for lumbar interbody fusion procedures.

Objectives: The objective of the study was to report technical modifications, learning curve, and short-term clinical results in minimally invasive transforaminal interbody fusion (MITLIF).

Materials and Methods: All MITLIF cases performed from 2018 July to March 2020 were included. First three authors were operating surgeons. Visual analog scores (VAS) scoring for pain, Macnab criteria, and Oswestry disability index (ODI) were used for outcome assessment. Operating time, radiation exposure, and complications were assessed separately in a group of 20 as per time sequence in series to assess the learning curve.

Results: A total of 61 patients were included. Various indications included spondylolisthesis, failed back surgery, calcified lumbar disc, and spondylodiscitis. Mean age was 47.08 ± 12.06. Intraoperative blood loss was 97.04 ± 25.58. Mean operating time and number of C-arm shots were 190.75 ± 37.11 and 159.3 ± 74.54, respectively, in initial 20 cases which however reduced in later operated cases. Significant improvement in VAS and ODI scores was observed at follow-up of 6.34 ± 4.67 months. Three cases needed surgical revision in the initial 20 cases, and there were no revision surgeries in later operated cases.

Conclusion: MITLIF could be done in failed back surgery cases, spondylodiscitis, and deformity corrections in addition to spondylolisthesis. It has advantages of less injury to soft tissues, maintaining the posterior tension band, decrease in blood loss and hospital stays, and early mobilization. However, it has longer learning curve and takes minimum 20 cases for the surgeon to acquire reasonable experience and confidence.

Keywords: Indications, learning curve, minimally invasive transforaminal interbody fusion, outcome

INTRODUCTION

Transforaminal lumbar interbody fusion (TLIF) has emerged as an accepted procedure for lumbar fusions.[1-4] While maintaining the ease of access to posterior structures for decompression and preserving ligamentous supports, studies have shown that open TLIF has shown a significantly lower complication rate while providing statistically significant clinical improvement as compared to posterior lumbar interbody fusion.[5] The adoption of minimally invasive procedure for spine transformed the open TLIF to minimally

Access this article online	
Website: www.jcvjs.com	Quick Response Code
DOI: 10.4103/jcvjs.jcvjs_112_21	

Reddy Ramanadha Kanala, Thirumal Yerragunta, Vamsi Krishna Yerramneni, Swapnil Kolpakawar, K. S. Vishwa Kumar, Arvind Suman

Department of Neurosurgery, Nizam's Institute of Medical Sciences, Hyderabad, Telangana, India

Address for correspondence: Dr. Vamsi Krishna Yerramneni, Department of Neurosurgery, Nizam's Institute of Medical Sciences, Panjagutta, Hyderabad - 500 082, Telangana, India. E-mail: vamsiky.ns@gmail.com

Submitted: 07-Aug-21 **Accepted:** 06-Nov-21
Published: 11-Dec-21

How to cite this article: Kanala RR, Yerragunta T, Yerramneni VK, Kolpakawar S, Kumar KS, Suman A. Minimally invasive transforaminal lumbar interbody fusion: Technical tips, learning curve, short-term clinical outcome, and brief review. J Craniovert Jun Spine 2021;12:387-92.

invasive TLIF (MITLIF). MITLIF has huge demand over the past two decades due to the advantages it offers in reducing intraoperative blood loss, reducing incidence of wound infections, and postoperative hematomas while preserving midline interspinous and supraspinous ligamentous complex and paraspinal muscle function by preservation of innervation.[6-8]

Authors in the current study reported various indications of MITLIF, results, short-term follow-up, and learning curve along with review of literature.

MATERIALS AND METHODS

This study includes all cases of MITLIF performed by the authors between July 2018 and December 2019. Patients underwent MITLIF with the placement of an interbody cage using a tubular retractor system at the author's institution. Indications for this surgery included Grade I spondylolisthesis, selective cases of Grade II spondylolisthesis, failed back surgery and degenerative scoliosis, and calcified disc prolapse. Conservative management of adequate length has been tried whenever indicated for sufficient length of time before offering surgery. All patients underwent preoperative clinical and radiological assessment. Patient's demographic details, clinical features, Oswestry disability index (ODI), and visual analog scores (VAS) for leg and back pain were used for clinical assessment in the pre- and post-operative period.

Imaging in the form of lumbosacral (LS) spinal X-rays (static and dynamic), magnetic resonance imaging, and computed tomography (CT) was performed.

Postoperatively, each patient underwent CT imaging of LS spine on day 1 to look for screw position and the extent of decompression. Patients were ambulated on postoperative day 1 and were discharged after 48 h of surgery. Duration of surgery, number of C arm shots taken (radiation exposure), and complications were assessed separately in a group of 20 as per time sequence in series to assess the learning curve. Initial 20 cases were (1–20) included in Group 1, later (21–40) in Group 2, and final (41–61) cases were in Group 3. Patient satisfaction was assessed at follow-up using the Macnab criteria.

Operative technique

Positioning and incision marking

Patient was positioned prone, and table alignment was manipulated to minimize the subluxation. C-arm was used to confirm the operative level in all cases. The C-arm positioning ensured that the spinous process is in midline, endplates of the vertebra should be parallel, and there is no rotation of the vertebrae. In each case, the disc space and lateral pedicle line were marked on anteroposterior (AP) and confirmed on lateral view X-rays obtained using C-arm [Figure 1a]. Paramedian incision of 3 cm length is made on either side, about 3–3.5 cm lateral to the midline, corresponding to the lateral pedicle border and vertically centered at the disc space. The fascial incision extends beyond the skin incision both cranially and caudally by around 3 or 4 mm for added mobility.

Screw placement

Muscle is split using blunt dissection with finger, from the cranial pedicle entry point to the caudal pedicle entry point. The transverse process and superior facet junction are palpated, and the Jamshidi needles are parked at the lateral border of the pedicles at the junction of upper 1/3 and the lower 2/3 of the pedicle height as visualized on X-ray. Tapping is done with needle tip aligned at the center of the pedicle until a depth of 20–25 mm, under C-arm guidance in AP view. At the end of this, the pedicle–body junction is reached and then a more medially directed trajectory is adopted guided by lateral view X-rays. Guide wires are then inserted through the Jamshidi needles in all pedicles, and their distal ends are anchored to the surgical drapes. Steps so far are illustrated in Figure 1.

Facetectomy and decompression

Dilators are now placed over the facets under C-arm guidance, and finally the tubular retractor system (MARS 3V, GLOBUS medical, Philadelphia, USA) is positioned and fixed in place. Under microscopic vision, facets are visualized after clearance of overlying muscle using monopolar cautery. Facets are cut using a chisel and hammer. For removing the medial facet, two cuts, one at the laminofacetal junction and one at the pars, are required followed by ligamentous disconnection using Kerrison rongeurs. Superior 1/3rd of lateral facet is also excised for complete visualization of the Kambin's triangle.

Disc space preparation and cage insertion

The disc space is accessed in between the exiting and the traversing nerve root. Annulus is cut with knife. Disc curettes, punches, disc shavers, and box curettes (REVOLVE system, GLOBUS medical, Philadelphia, USA) were used for completing the discectomy and freshening the end plates. Bone graft which is obtained from the facets is packed in the ventral portion of the disc space following which a cage filled with bone was placed. Placement of cage was done under guidance of C-arm.

Screw placement and wound closure

Screws are inserted over the guide wires, and subsequently rods are placed and compression done to snugly hold the interbody cage *in situ*. These steps are illustrated in Figure 2.

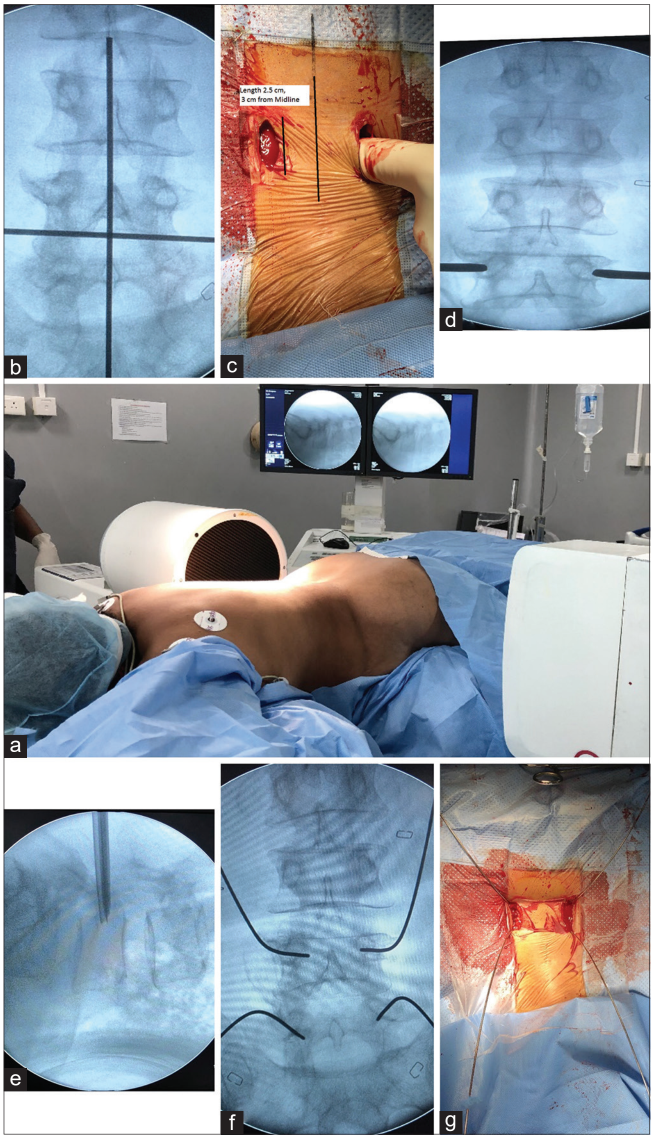

Figure 1: (a) Position of patient, (b) Images from C arm showing true anteroposterior view, (c) Image showing bilateral 2.5 cm length skin incision and 3 cm from midline, (d) Initial direction of Jamshidi needle, (e) Jamshidi needle at the pedicle–body junction, after this medial direction of Jamshidi needle required, (f) Final guidewire placement in anteroposterior view, (g) Distal ends of guidewires anchored to the surgical drape

Technique pertaining to spondylodiscitis

In spondylodiscitis cases if the adjacent vertebral bodies have healthy pedicles and partial destruction of body, screws were placed in pathological vertebrae, otherwise adjacent healthy vertebrae were chosen for the placement of screws. Facetectomy in lumbar spine and transpedicular approach in thoracic spine was taken to access the disc space. Complete debridement of necrotic disc material was done, and it was sent for HPE and culture and GeneXpert for tuberculosis (TB). In cases of suspected and proven TB, antituberculosis treatment (ATT) was started immediately, and the drugs were continued for 18 months.[9]

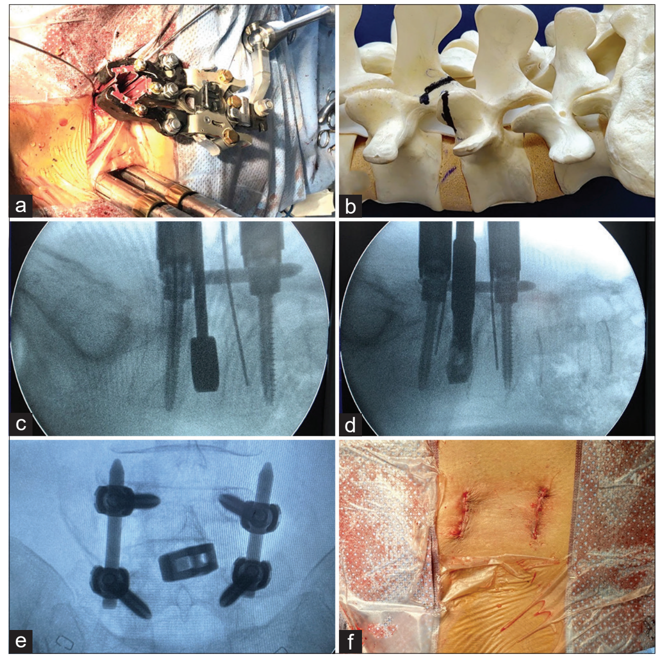

Figure 2: (a) Tubular retractor system placement, (b) spine model showing cuts for facetectomy, (c) intraoperative C-arm image one side screw placement and insertion of Trailer, (d) image showing final cage placement, (e) anteroposterior view of C-arm showing final implants and cage position, (f) Skin incision after closure

Statistical analysis

Continuous variables were analyzed by descriptive statistics. Paired *t*-test and one-way ANOVA were used for normally distributed data, and Welch Satterthwaite *t*-test was used for variables with unequal variances. Categorical variables were analyzed using Chi-square test.

$P < 0.05$ was considered statistically significant.

IBM SPSS V24 (IBM Corp., New York, USA) was used for analysis of data.

RESULTS

A total number of patients was 61. Demographics, presenting symptoms, various indications, mean duration of hospital stay, pre- and postoperative VAS, pre and postoperative ODI, postoperative modified Macnab criteria, and radiation exposure (number of shots) were depicted in Table 1. The surgical procedure remained fairly constant. 57 patients underwent unilateral facetectomy with discectomy, single interbody cage placement, and bilateral pedicle screw placement. Four patients were subjected to bilateral facetectomy, although with single sided cage insertion, and these procedures contributed to a prolongation in operative time.

Mean blood loss was 97.04 ± 25.58 ml. Authors have assessed mean operating time (OT time) and C-arm shots in

Table 1: Demographic details, various indications, intraoperative parameters, outcome results, and complications

Demographic details	Number
Total number	61
Age (mean±SD)	47.08±12.06
Female:Male	1.6:1
Symptoms (number)	
Unilateral radicular pain	30
Bilateral radicular pain	13
Claudication	10
Backache	8
Primary pathology	
Single level listhesis	38
Grade 1	29
Grade 2	9
Two level listhesis	3
Failed back surgery syndrome	7
Spondylodiscitis	12
Calcified lumbar disc	1
Intraoperative parameters	
Average time duration of the procedure (min)	169.29±32.93
Average number of C arm shots	143.51±51.03
Unilateral facetectomy	57
Bilateral facetectomy	4
Average duration of hospital stay (mean±SD)	3.43±1.20
Outcome parameters	
Mean follow up (months)	6.34±4.67
Leg VAS	
Preoperative	7.78±0.96
Postoperative	2.49±1.34
P	<0.05
Back VAS	
Preoperative	7.49±1.05
Postoperative	2.77±1.34
P	<0.05
Modified Macnab criteria	
Excellent to good	49
Fair	11
Poor	1
ODI	
Preoperative	67.96±8.74
Postoperative	33.45±13.00
P	<0.05
Complications	
Screw malposition	3
Cage displacement	1
Dural tear	2
Wound CSF leak	Nil

ODI - Oswestry disability index; SD - Standard deviation; VAS - Visual analog score; CSF - Cerebrospinal fluid

three groups of patients. As experience and number of cases increased, a gradual reduction in operation time and radiation exposure was observed [depicted in Figure 3].

Mean postoperative hospital stay was 3.5 days. 5 out of 61 patients had complications that include screw malposition in three patients requiring repositioning, one patient had foot drop owing to medial breach of the pedicle, one patient had cage extrusion. Among three patients with screw malposition, two patients were in initial 20 cases and one in Group 2. Two patients had dural tear in initial 20 cases, but no postoperative CSF leak from the wound was noted. One patient had unilateral foot inversion dystonia for duration of 1 month in the postoperative period which resolved spontaneously. One patient required reexploration for contralateral facetectomy. It was necessitated by the persistence of radicular pain on the side contralateral to initial facetectomy. Authors have not assessed signs of fusion because of variable follow-up in study population.

DISCUSSION

MITLIF was first described by Foley *et al*.[10] in the early 2000. The reported benefits of MITLIF include minimized muscle injury intraoperatively and a good postoperative outcome with minimal blood loss, lesser postoperative pain, shorter hospital stay, earlier ambulation, and earlier return to work[7,11] compared to open TLIF.

Learning curve in the technique and decision making

MITLIF has a steep learning curve. The operating time and the number of X-rays to be taken have reduced after twenty cases. Even the screw malposition and the cage displacement requiring reexploration were done in one case after 20 cases. Our operating time was >200 min in the initial 15 cases, and it has come down to an average time of 127 min in the subsequent cases. Selective Grade II listhesis, failed back surgery, and spondylodiscitis cases were taken up for surgery as the authors gained more confidence. Unilateral facetectomy was performed in the initial 25 cases, and bilateral facetectomy was done when indicated in cases of severe stenosis with bilateral symptoms as the time duration of surgery reduced and ease of doing the procedure got better. Most of the cages the authors used in the latter half of the cases were 11 mm and that became possible with better disc removal and preparation of endplates [Table 2]. Usage of large size shavers was avoided to prevent end plate damage. In the absence of the navigation, the Grade II case selection was chosen if the patient was not obese, had a partially reducible slip with normal bone density and absence of scoliosis. L4/5 Grade II slips are relatively easy to operate compared to L5/S1 in view of better visibility on C-arm. To have more cosmetic appearing scar a 2.5–3 cm incision on either side of the midline was taken and closure done with subcuticular sutures.

Various studies on learning curve suggested that the surgeon needs to perform around 40 cases to achieve technical efficiency with minimal complications. One of the studies include 90 single level MITLIF performed by single surgeon

Table 2: Learning curve and technical modifications in initial and later half of total number of cases

Initial 30 cases	30-60 cases
Senior author was chief surgeon and assisted by 2nd and 3rd author	Chief surgeons were 2nd or 3rd author with the help of senior author
Skin Incision was 3.5 to 4 cm on either side of the midline	2.5 cm on either side of midline
Screw repositioning was done in two cases	No screw revisions were done
Facetectomy was done with the drill	Chisel and hammer was used for facetectomy
7 to 9 mm cages were used in initial cases	11 mm cages were used in later cases
Average operating time was 200 min	Operating time was 120 min

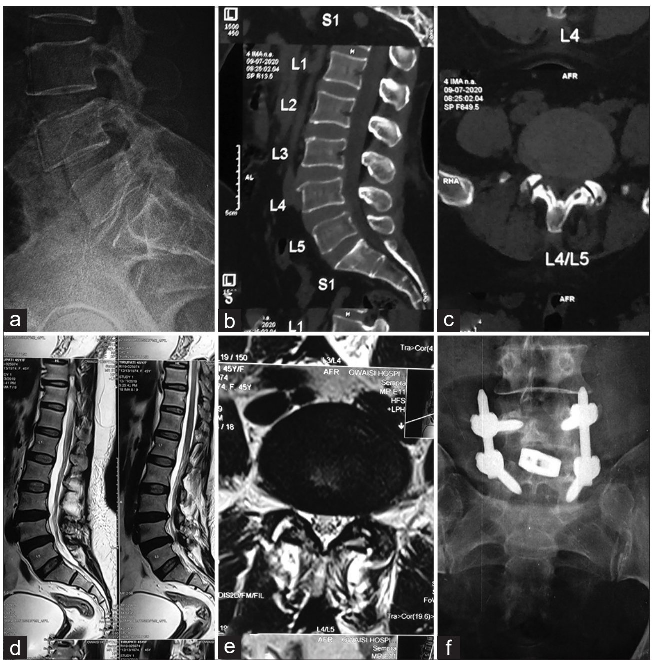

Figure 3: (a) Lateral roentgenogram showing L4-L5 Grade 1 listhesis, (b) computed tomography lumbosacral spine sagittal section, (c) computed tomography Axial section of L4-L5 disc level, (d) sagittal magnetic resonance imaging of lumbosacral spine, (e) axial magnetic resonance imaging image of L4-L5 level showing bilateral foraminal stenosis, (f) postoperative X-ray lumbosacral spine anteroposterior view showing implants *in situ*

Lee *et al*.[12] concluding that technical skillfulness for MITLIF was attained after 44 cases and patients operated after this achieved benefits of the procedure.

Silva *et al*.,[13] in their study of learning curve for MITLIF taking complication rates as the measure observed that 50% learning curve achieved by 12 and 90% learning curve by 39 cases.

Epstein *et al*.[14] in their review of various studies on learning curve observed various range of 20–40 cases as the minimum learning curve.

Modifications of minimally invasive transforaminal interbody fusion technique: Unilateral screw fixation

Unilateral screw fixation has been attempted to minimize morbidity, time, and radiation exposure. Deutsch *et al*.[15] reported results of MITLIF with unilateral pedicle screw fixation in twenty patients. There was notable improvement in postoperative outcome and 65% of patients showed signs of fusion in CT after 6 months of follow-up. Nevertheless, long-term result analysis of unilateral pedicle system by Choi *et al*.[16] showed that operating time and blood loss was less; however, fusion rates at 2-year follow-up were less compared to the bilateral screw fixation.

Minimally invasive transforaminal interbody fusion versus open transforaminal interbody fusion

Many studies have been published comparing the MI versus Open TLIF procedure though there is a lack of well-designed adequately powered study to draw definitive conclusions. However, most individual case series and reviews agree that intraoperative blood loss and hospital stay are less in MITLIF as compared to open TLIF. Some studies report longer operating times with MITLIF while others contend that. Patient reported long-term clinical outcomes does not seem to differ significantly between both the groups.[17-20]

On comparison of postoperative complications in one of the largest series of MITLIF by Wong *et al*., it was seen that MITLIF is associated with lower rate of deep surgical site infections and requirement for revision surgeries. However, no observed difference was noted in cerebrospinal fluid leaks, neurologic deficits, or mechanical malpositioning between the open and MITLIF group.[17] Wong *et al*. also noted that revision surgery incidence was more for adjacent segment degeneration in Open TLIF group of patients. The aforementioned difference could possibly be attributed to less distortion of anatomy and destabilization in MITLIF. Various meta-analysis[18] done on studies comparing open versus MI TLIF concluded that the MI TLIF had significantly lower blood loss, length of stay complication, and infection rates; however, the MIS group was associated with longer fluoroscopy time.[19] Lin *et al*. in addition to the lesser blood loss and faster recovery reported lower incidence of adjacent segment disease.[21]

Endoscopic transforaminal interbody fusion versus minimally invasive transforaminal interbody fusion

Endo fusion techniques are gaining ground in the recent past. The advantages of using endoscope in the spinal fusion techniques include least tissue injury and fair complications. The current literature[22] on endoscopic TLIF is limited to case series and a technical note. The technique has limited indications in a very selective group of low-grade listhesis while having a longer learning curve.[23] The relative contraindications are cases with narrow disc space, very small Kambin's triangle, scoliosis, high-grade slips requiring reduction, and severe central canal stenosis. As the technique of endoscopic TLIF does not generate a good autologous bone graft, artificial bone graft usage and overall long-term bone fusion rates remain a major concern. Although the technique looks well futuristic, it is yet to prove its wider application and require major advances in terms and technique and the technology.

CONCLUSIONS

MITLIF is emerging as the preferred procedure for the lumbar interbody fusion procedure. In addition to spondylolisthesis, the procedure could well be feasible in failed back surgery cases, spondylodiscitis, and curvature corrections. It has advantages of less injury to the soft tissues, maintaining the posterior tension band, less blood loss, shorter hospital stays, and early mobilization. However, the learning curve is steep, and more radiation exposure for the surgeon is concerns. To achieve reasonable level of skill, a minimum of 20 cases needs to be performed.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Harms J, Rolinger H. A one-stager procedure in operative treatment of spondylolistheses: Dorsal traction-reposition and anterior fusion (author's transl). Z Orthop Ihre Grenzgeb 1982;120:343-7.
2. Lowe TG, Tahernia AD, O'Brien MF, Smith DA. Unilateral transforaminal posterior lumbar interbody fusion (TLIF): Indications, technique, and 2-year results. J Spinal Disord Tech 2002;15:31-8.
3. Rosenberg WS, Mummaneni PV. Transforaminal lumbar interbody fusion: Technique, complications, and early results. Neurosurgery 2001;48:569-74.
4. Moskowitz A. Transforaminal lumbar interbody fusion. Orthop Clin North Am 2002;33:359-66.
5. de Kunder SL, van Kuijk SM, Rijkers K, Caelers IJ, van Hemert WL, de Bie RA, *et al.* Transforaminal lumbar interbody fusion (TLIF) versus posterior lumbar interbody fusion (PLIF) in lumbar spondylolisthesis: A systematic review and meta-analysis. Spine J 2017;17:1712-21.
6. Fan S, Hu Z, Zhao F, Zhao X, Huang Y, Fang X. Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: Minimally invasive procedure versus conventional open approach. Eur Spine J 2010;19:316-24.
7. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR. Comparative outcomes of minimally invasive surgery for posterior lumbar fusion: A systematic review. Clin Orthop Relat Res 2014;472:1727-37.
8. Tian NF, Wu YS, Zhang XL, Xu HZ, Chi YL, Mao FM. Minimally invasive versus open transforaminal lumbar interbody fusion: A meta-analysis based on the current evidence. Eur Spine J 2013;22:1741-9.
9. Yeraagunta T, Yerramneni VK, Kanala RR, Gaikwad G, Kumar HD, Phutane AS. Minimally invasive spinal fusion and decompression for thoracolumbar spondylodiscitis. J Craniovertebr Junction Spine 2020;11:17-21.
10. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. Spine (Phila Pa 1976) 2003;28:S26-35.
11. Lee KH, Yue WM, Yeo W, Soeharno H, Tan SB. Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. Eur Spine J 2012;21:2265-70.
12. Lee KH, Yeo W, Soeharno H, Yue WM. Learning curve of a complex surgical technique: Minimally invasive transforaminal lumbar interbody fusion (MIS TLIF). J Spinal Disord Tech 2014;27:E234-40.
13. Silva PS, Pereira P, Monteiro P, Silva PA, Vaz R. Learning curve and complications of minimally invasive transforaminal lumbar interbody fusion. Neurosurg Focus 2013;35:E7.
14. Epstein NE. Learning curves for minimally invasive spine surgeries: Are they worth it? Surg Neurol Int 2017;8:61.
15. Deutsch H, Musacchio MJ Jr. Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation. Neurosurg Focus 2006;20:E10.
16. Choi UY, Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, *et al.* Unilateral versus bilateral percutaneous pedicle screw fixation in minimally invasive transforaminal lumbar interbody fusion. Neurosurg Focus 2013;35:E11.
17. Wong AP, Smith ZA, Stadler JA 3rd, Hu XY, Yan JZ, Li XF, *et al.* Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF): Surgical technique, long-term 4-year prospective outcomes, and complications compared with an open TLIF cohort. Neurosurg Clin N Am 2014;25:279-304.
18. Phan K, Rao PJ, Kam AC, Mobbs RJ. Minimally invasive versus open transforaminal lumbar interbody fusion for treatment of degenerative lumbar disease: Systematic review and meta-analysis. Eur Spine J 2015;24:1017-30.
19. Ge DH, Stekas ND, Varlotta CG, Fischer CR, Petrizzo A, Protopsaltis TS, *et al.* Comparative analysis of two transforaminal lumbar interbody fusion techniques: Open TLIF Versus Wiltse MIS TLIF. Spine (Phila Pa 1976) 2019;44:E555-60.
20. Mummaneni PV, Bisson EF, Kerezoudis P, Glassman S, Foley K, Slotkin JR, *et al.* Minimally invasive versus open fusion for Grade I degenerative lumbar spondylolisthesis: Analysis of the quality outcomes database. Neurosurg Focus 2017;43:E11.
21. Lin GX, Park CK, Hur JW, Kim JS. Time course observation of outcomes between minimally invasive transforaminal lumbar interbody fusion and posterior lumbar interbody fusion. Neurol Med Chir (Tokyo) 2019;59:222-30.
22. Wu J, Liu H, Ao S, Zheng W, Li C, Li H, *et al.* Percutaneous endoscopic lumbar interbody fusion: Technical note and preliminary clinical experience with 2-year follow-up. Biomed Res Int 2018;2018:5806037.
23. Ahn Y, Youn MS, Heo DH. Endoscopic transforaminal lumbar interbody fusion: A comprehensive review. Expert Rev Med Devices 2019;16:373-80.