Comparison of minimally invasive and open transforaminal lumbar interbody fusion in the treatment of single segmental lumbar spondylolisthesis: minimum two-year follow up

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Background: Compare the efficacy and safety of minimally invasive and open transforaminal lumbar interbody fusion (TLIF) in the treatment of single segmental lumbar spondylolisthesis.

Methods: From 2010-01 to 2015-10, in total, 167 patients with single segmental spondylolisthesis treated by TLIF were included, 79 cases in minimally invasive TLIF (MI-TLIF) group and 88 cases in open TLIF group. The peri-operative parameters of operative time, estimated blood loss and length of postoperative hospital stay was recorded, as well as complications. Visual Analogue Scale (VAS) of low back pain and leg pain, and Oswestry Disability Index (ODI) were used to assess the pain and functional outcomes at pre-operatively, 3 months/1 year/2 years/5 years after operation. The radiographic parameters of posterior height of the intervertebral space and segmental lordosis were measured too.

Results: No significantly difference was found at baseline characteristic data of age, gender ratio, the percentage of degenerative and isthmic spondylolisthesis, the percentage of slip, and segmental distribution between MI-TLIF and open TLIF groups. MI-TLIF group had less estimated intra-operative blood loss (163.7±49.6 mL) than open TLIF group (243.3±70.2 mL, P<0.001) and had shorter post-operative hospital stay (5.8±1.4 days) than open TLIF group (7.3±2.9 days, P<0.001). Both MI-TLIF and open TLIF can significantly reduce the VAS of low back pain, VAS of leg pain, ODI, and improve the posterior height of the intervertebral space and segmental lordosis, but no significantly difference was found of them between two groups.

Conclusions: Our study suggests that MI-TLIF is a safe and effective choice in the treatment of lower grade lumbar spondylolisthesis (grade II or less), and it has advantages of less blood loss, postoperative hospital stay when compared to open TLIF.

Keywords: Minimally invasive; transforaminal lumbar interbody fusion (TLIF); lumbar spondylolisthesis; lumbar stenosis

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Introduction

Spondylolisthesis is one of the common disorders in lumbar spine region, and often results in lumbar stenosis, with symptoms of lower back pain, leg pain, neurogenic claudication and decreased function (1-4). Surgical intervention is recommended if the symptoms can't be relieved by conservative therapy (5-10).

Transforaminal lumbar interbody fusion (TLIF) is world widely used as standard treatment for lumbar spondylolisthesis (11,12). However, traditional open TLIF may injury the paraspinal muscle (13), leading to a hard recovery of extensor muscle strength (14). Minimally invasive TLIF (MI-TLIF) was aided with the tubule and endoscopy to decompression and interbody fusion (15,16), was reported had advantages of less blood loss, quicker recovery and lower wound infection (17). Although there were some short-term follow-up literature report about using MI-TLIF in treatment of lumbar spondylolisthesis (18-21), it still questioned by its limited operative view and space (22,23), hard learning curve (24) and may higher incidence of hardware-related complications (25).

The present study evaluated the degenerative or isthmic spondylolisthesis patients treated with MI-TLIF or open TLIF. The data is based on minimum 2-year follow-up, and part of five-year follow-up, to assessment the middle term efficacy and safety.

Methods

Inclusion criteria

(I) Adult patients with age >18 years old;
(II) Degenerative or isthmic spondylolisthesis (Meyerding grade I or II);
(III) Symptoms can't be relieved with conservative therapy at least 6 months;
(IV) Single segmental spondylolisthesis (include L3–4, L4–5 and L5–S1).

Patient population

The total of 167 patients with grade I or II single segmental spondylolisthesis were included in this study. There were 79 patients in MI-TLIF group, with an average age of 58.1±12.8 years old, 33 males and 46 females, 45 of them were degenerative spondylolisthesis and 34 of them were isthmic spondylolisthesis, segmental distribution were: L3/4: 6 cases, L4/5: 44 cases; L5/S1: 29 cases. While 88 patients in open TLIF group, with averaged age of 55.3±14.0 years old, 38 males and 50 females, 52 of them were degenerative spondylolisthesis and 36 of them were isthmic spondylolisthesis, segmental distribution were: L3/4: 6 cases, L4/5: 51 cases; L5/S1:31 cases. The detailed characteristic data were summarized in *Table 1*.

Surgical procedure

MI-TLIF group: patients underwent general anesthesia and placed as prone position on a radiolucent spine operative table. C-arm X-ray machine was used to make the back skin makers (*Figure 1*). Firstly, the skin wound incision was made at the non-symptomatic side, the gaps of the paraspinal muscles were separated and to approach the pedicle screw entry point, which can be directly touched by the surgeon's finger. Then, a cannulated needle was used to insert into the pedicle under C-arm X-ray machine guidance, and a blunt-tipped guide wire was placed inside of the cannulated needle, forward into the ventral third of the vertebral body, the surgeon can feel the wire is approaching the anterior cortex at the vertebral body now. After tapping the screw trajectory, the screw was inserted, and a rod was pre-installed. Secondly, the same procedure was performed at the symptomatic side, but until the blunt-tipped guide wire inserted into the ventral third of the vertebral body. The tubular was inserted to perform the facetectomy and interbody fusion and the part reduction of spondylolisthesis can be observed at this time. The screws were inserted after the procedure of facetectomy and interbody fusion, the contralateral side decompression was performed by transmedian way. Thirdly, the non-symptomatic side screw cap that pre-installed was loosed, rods were installed at height different upper and lower screws at both sides, and the second part reduction of spondylolisthesis can be observed at this time. After detecting the never root, the wound was closed layer by layer. If the patient had severe symptoms of the both sides, the tubular was inserted into both sides to perform decompression.

Open TLIF: patients were placed at the same position as the MI-TLIF, the midline wound incision was made, and the paraspinal muscles were dissected from the spinous process, then perform the facetectomy and interbody fusion, if the patients only had one side symptom, the contralateral side decompression was performed by transmedian way, if they had severe symptoms at both sides, the facetectomy and decompression was performed at both sides. The screws were inserted and rods were installed after procedure of

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Table 1 Comparisons of the baseline data between MI-TLIF and Open TLIF groups

Items	MI-TLIF (N=79)	Open TLIF (N=88)	t/χ^2	P
Age (years)	58.1±12.8	55.3±14.0	1.341	0.182
Gender (M:F)	33:46	38:50	0.034	0.854
Degenerative:isthmic spondylolisthesis	45:34	52:36	0.077	0.781
Percentage of slip (%)	26.7±14.2	28.5±13.2	–0.862	0.390
Segmental distribution			0.098	0.952
L3/4	6	6		
L4/5	44	51		
L5/S1	29	31		
No. of minimum 2-year follow up	77	85	–	1.000*
No. of complete 5-year follow up	32	37	0.041	0.840

*, result from fisher's exact test. MI-TLIF, minimally invasive transforaminal lumbar interbody fusion; Open TLIF, open transforaminal lumbar interbody fusion.

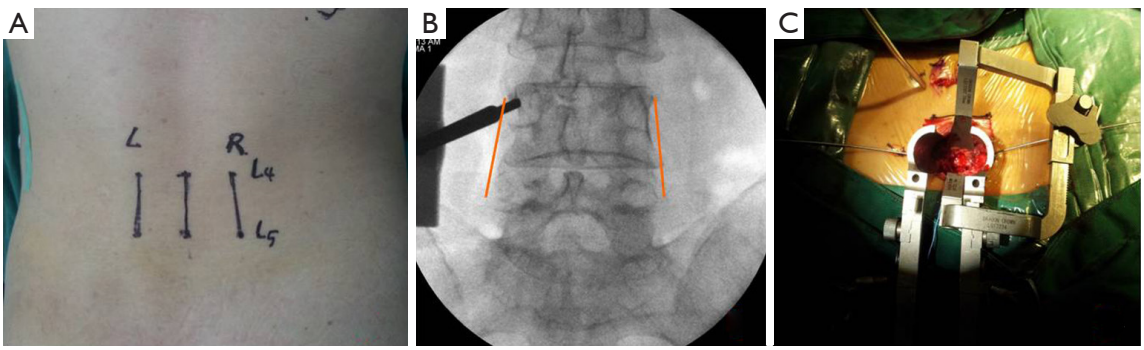

Figure 1 The intra-operative photos of the minimally invasive transforaminal lumbar interbody fusion. (A) The skin wound incision line makers made pre-operatively under the C-arm X-ray machine; (B) the anteroposterior film of the lumbar spine, two sides lines mean the skin wound incision line makers located 5–10 mm lateral side of the screw entry point; (C) the tubular (retaining retractor) was inserted to perform the facetectomy and interbody fusion.

facetectomy and interbody fusion.

Outcomes measures

The operative time, estimated intra-operative blood loss, length of post-operative hospital stay were recorded, as well as the complications of dural tear, post-operative wound infection, screw misplacement, bone nonunion and re-operation. Visual Analogue Scale (VAS) of low back pain, VAS of leg pain and Oswestry disability index (ODI) were assessed at pre-operation, 3 months after operation, 1 year after operation, 2 years after operation and 5 years after operation. The posterior height of the intervertebral space and segmental lordosis (*Figure 2*) were measured at the lateral X-ray films at pre-operation, 3 months after operation, 1 year after operation, 2 years after operation and 5 years after operation too.

Statistical analysis

All data were analyzed at IBM SPSS Statistics (SPSS v22, IBM Corp., Armonk, NY, USA). The continuous data between MI-TLIF and open TLIF groups were compared by independent sample *t*-test, categorical data was compared

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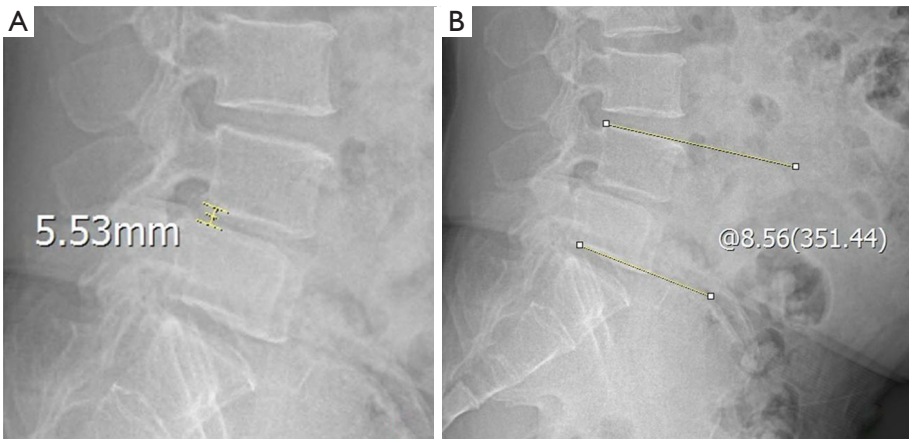

Figure 2 The posterior height of the intervertebral space (A) and segmental lordosis (B) was directly measured from the STARPACS system (INFINITT, Seoul, South Korea).

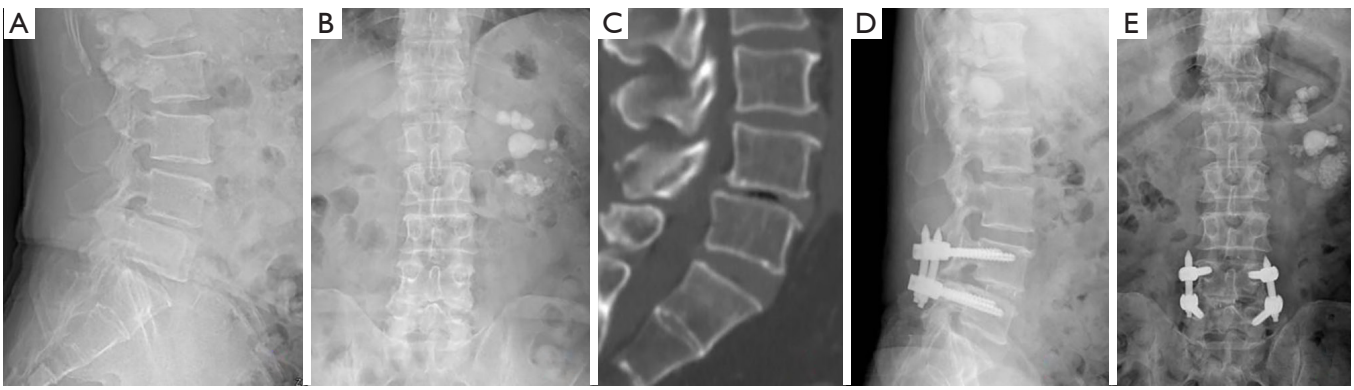

Figure 3 A type patient diagnosed as L4–5 Meyerding grade I spondylolisthesis (A, pre-operative lateral film; B, pre-operative anteroposterior film; C, the sagittal reconstruction of CT scans), MI-TLIF was performed on him, the slip was reduced and the symptom was disappeared after operation (D, post-operative lateral film; E, post-operative anteroposterior film).

by chi-squared test. The data that measured at different time points of pre-operation, 3 months after operation, 1 year after operation, 2 years after operation and 5 years after operation were tested by One-way analysis of variance (ANOVA) with repeated measures. Statistical significance was indicated at $P<0.05$.

Results

No significant difference was found at baseline characteristic data of age, gender ratio, the percentage of degenerative and isthmic spondylolisthesis, the percentage of slip, and segmental distribution between MI-TLIF and open TLIF groups (*Table 1*). In MI-TLIF group (*Figure 3*), two patients were lost at follow up of the 2 years after operation, while three patients were lost at follow-up of the 2 years after operation in open TLIF. Therefore, the total of 162 patients (77 patients in MI-TLIF and 85 patients in open TLIF) had minimum 2 years follow-up. In above 162 patients, 69 of them (32 patients in MI-TLIF and 37 patients in open TLIF) completed the 5 years follow-up.

Peri-operative parameters

The operative time in MI-TLIF group was 145.5±21.5 minutes, while the open TLIF group was 151.4±19.9 minutes, no statistically significant difference was observed (P=0.068). However, the estimated intra-operative blood loss in MI-

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Table 2 The perioperative parameters and complications between MI-TLIF and open TLIF groups

Parameters	MI-TLIF (N=79)	Open TLIF (N=88)	t	P
Operative time (min)	145.5±21.5	151.4±19.9	−1.834	0.068
Estimated intra-operative blood loss (mL)	163.7±49.6	243.3±70.2	−8.376	<0.001
Length of post-operative hospital stay (d)	5.8±1.4	7.3±2.9	−4.004	<0.001
Complications				
Dural tear	1	3	–	0.623*
Screw misplacement	1	1	–	1.000*
Wound infection	0	2	–	0.498*
Bone nonunion	1	1	–	1.000*
Contralateral radiculopathy	4	3	–	0.709*
Re-operation	3	2	–	0.668*

*, results from fisher's exact test. MI-TLIF, minimally invasive transforaminal lumbar interbody fusion; Open TLIF, open transforaminal lumbar interbody fusion.

TLIF group was 163.7±49.6 mL. significantly less than the 243.3±70.2 mL in open TLIF group (P<0.001). The length of post-operative hospital stay in MI-TLIF group was 5.8±1.4 days, significantly shorter than the 7.3±2.9 days in open TLIF group (P<0.001) (*Table 2*).

Pain and functional outcomes

Both MI-TLIF and open TLIF can significantly reduce the VAS of low back pain, VAS of leg pain and ODI. No significantly difference was found when compare the VAS of low back pain, VAS of leg pain and ODI at all follow-up time points between MI-TLIF and open TLIF groups (*Table 3*).

Radiographic outcomes

Both MI-TLIF and open TLIF can significantly improve the posterior height of the intervertebral space and segmental lordosis. No significantly difference was found when comparing the posterior height of the intervertebral space and segmental lordosis at all follow-up time points between MI-TLIF and open TLIF groups (*Table 3*).

Complications and reoperations

Dural tear was occurred at one case in MI-TLIF group and three cases in open TLIF group. Both groups had one case with screw misplacement and performed reoperation. No deep wound infection was observed, and two superficial infections in open TLIF group. There were four cases and three cases of contralateral radiculopathy in MI-TLIF group and open TLIF group respectively, four (two in MI-TLIF group and two in open TLIF group) of them relieved after conservative treatment, three (two in MI-TLIF group and one in open TLIF group) of them were performed the reoperation. Both groups had one case of bone nonunion, and no clinical symptom was complained, no screw lose or breakage was observed and no further surgery was performed on them (*Table 2*).

Discussion

There are many muscles at the posterior the lumbar spine that support our body, the back muscle injury is one of the main problems of traditional open posterior lumbar surgery (26,27). Hu *et al.* (13) reported that the traditional powerful muscle retraction will not only cause multifidus injury, but also cause long-term multifidus atrophy after posterior lumbar surgery. Gejo *et al.* (14) found that the paraspinal muscle injury was directly related to the muscle retraction time, longer retraction time will cause more severe muscle injury. The minimally invasive posterior lumbar technique can avoid these muscle injuries and does not need to disrupt the tendon attachment of these paraspinal muscles (28).

However, the MI-TLIF is more complicated than the traditional open TILF. It may have higher complication rate at the beginning of learning (28) and longer the operative

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Table 3 The clinical and radiographic outcomes between MI-TLIF and open TLIF groups

Parameters	MI-TLIF (N=79)	Open TLIF (N=88)	t	P
VAS of low back pain				
Pre-operation	6.78±1.48	6.70±1.53	0.349	0.727
3 months after operation	1.73±0.92*	1.92±1.01**	–1.297	0.196
1 year after operation	1.60±1.07*	1.74±1.01**	–0.850	0.397
2 years after operation	1.68±1.11*	1.70±1.08**	–0.082	0.935
5 years after operation	1.63±1.20*	1.84±0.99**	–0.772	0.443
VAS of leg pain				
Pre-operation	7.12±1.33	6.86±1.23	1.295	0.197
3 months after operation	1.83±1.25*	1.69±1.30**	0.711	0.478
1 year after operation	1.69±1.38*	1.64±1.30**	0.213	0.831
2 years after operation	1.84±1.30*	1.71±1.31**	0.635	0.526
5 years after operation	1.77±1.39*	1.67±1.33**	0.301	0.764
ODI				
Pre-operation	60.7±10.6	62.1±10.6	–0.866	0.388
3 months after operation	27.6±7.5*	28.5±8.8**	–0.713	0.477
1 year after operation	23.5±5.8*	24.4±7.2**	–0.876	0.382
2 years after operation	23.3±6.9*	23.6±6.3**	–0.321	0.749
5 years after operation	25.3±6.3*	25.3±6.2**	–0.060	0.952
Posterior height of the intervertebral space (mm)				
Pre-operation	5.45±2.19	5.73±2.24	–0.805	0.422
3 months after operation	10.45±1.92*	10.29±1.67**	0.575	0.566
1 year after operation	10.07±1.61*	10.2±1.46**	–0.386	0.700
2 years after operation	9.75±1.75*	9.97±1.51**	–0.860	0.391
5 years after operation	9.68±1.59*	9.69±1.54**	–0.028	0.978
Segmental lordosis (°)				
Pre-operation	7.05±4.86	6.83±5.18	0.277	0.782
3 months after operation	12.46±3.91*	13.30±3.69**	–1.429	0.155
1 year after operation	12.17±3.43*	13.02±3.74**	–1.526	0.129
2 years after operation	12.11±3.36*	12.78±3.61**	–1.230	0.221
5 years after operation	11.80±2.61*	12.36±4.04**	–0.667	0.507

*, P<0.05 compared to the pre-operative data of MI-TLIF group; **, P<0.05 compared to the pre-operative data of open TLIF group. MI-TLIF, minimally invasive transforaminal lumbar interbody fusion; Open TLIF, open transforaminal lumbar interbody fusion; VAS, Visual Analog Scale; ODI, Oswestry Disability Index.

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time (29), because of the limited operative view and space. Lee *et al.* (24) found that surgeons need perform about 44 surgeries to achieve the technical proficiency. In our study, the operative time of earlier surgery is truly longer than the later ones, after into the technical proficiency stage, we found MI-TLIF dissect less tissue, and can save lots of time. We found no significantly difference of operative time between MI-TLIF and open TLIF, and the mean data of MI-TLIF was 145.5±21.5 min, a little less than the open TLIF of 151.4±19.9 min.

The intra-operative blood loss and length of post-operative hospital stay are significant less in MI-TLIF found by our present study, which are consistent to the previous studies about MI-TLIF in treatment of lumbar stenosis with or without spondylolisthesis (17,18).

The goal of minimally invasive technique is not only limited to less tissue trauma, less blood loss and shorter hospital stay, the clinical outcome is very important to assess the efficacy of MI-TLIF. Singh *et al.* (30) compared the 33 single-level MI-TLIF versus 33 single-level open TLIF in the treatment of degenerative lumbar diseases, they found the MI-TLIF had the better reduction of VAS scores. In our present study, although the mean value of post-operative VAS of low back pain in MI-TLIF group is less than the open TLIF group, no significant difference was found in VAS and ODI between MI-TLIF and open TLIF, similar clinical outcomes were achieved by MI-TLIF and open-TLIF.

The indications of MI-TLIF in treatment of lumbar spondylolisthesis were still uncertain, in our study, only Meyerding grade I or II patients were included. Quraishi and Rampersaud reported (31) that used bilateral MI-TLIF in the treatment of Meyerding grade III spondylolisthesis, and suggested that it can correct focal deformity, achieve excellent radiographic and clinical outcomes, which was similar to the open TLIF, however, most surgeons use the MI-TLIF in treatment of lower grade lumbar spondylolisthesis currently (19), still without lager case series and compared study about MI-TLIF in treatment of high grade lumbar spondylolisthesis.

There were some limitations of our present study. Firstly, assigning the patients into MI-TLIF and open-TLIF is not randomized, therefore, it may have a potential risk of selection bias (32). Secondly, most of the patients were only followed up for 2 years, only 69 of them had completed the 5 years follow-up, further longer term follow-up data is needed. Finally, only single segmental Meyerding grade I or II spondylolisthesis patients were included, patients with spondylolisthesis more than one level or high than Meyerding grade II should be investigated in the future.

Conclusions

We suggest that MI-TLIF is a safe and effective choice in the treatment of lower grade lumbar spondylolisthesis (grade II or less), and it has advantages of less blood loss, postoperative hospital stay when compared to open TLIF.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This paper has received ethical approval from the Institutional Review Board of The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University.

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