CLINICAL ARTICLE

Psychological and Functional Comparison between Minimally Invasive and Open Transforaminal Lumbar Interbody Fusion for Single-Level Lumbar Spinal Stenosis

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Objective: The aim of this study was to investigate whether treatment with minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF) causes patients suffering from lumbar spinal stenosis (LSS) to experience less anxiety and better clinical efficacy than open transforaminal lumbar interbody fusion (TLIF).

Methods: In this retrospective cohort study, we analyzed 86 patients, including 46 male patients and 41 female patients, who suffered from single-segmental lumbar spinal stenosis in our department between January 2016 and January 2018. They were divided into two groups: a control group (n = 46), for patients who underwent open TLIF surgery, and an experimental group (n = 40), for patients who underwent Mis-TLIF surgery. All patients were evaluated based on operation time, intraoperative blood loss, hospital stay, visual analogue scale (VAS), Oswestry disability index (ODI), hospital anxiety depression scale (HADS), fusion rate, and complications (screw misplacement and loosening, cerebrospinal fluid leakage, infection, and delayed wound healing). Patient characteristics were compared within and between groups.

Results: The average incision length was 3.64 ± 0.476 cm in the experimental group, which was smaller than that (8.11 ± 2.406 cm) in the control group ($P < 0.05$). The operation time of the experimental group was a little longer than that of the control group. The intraoperative blood loss and hospital stay in the experimental group were less than those in the control group.

The mean preoperative low back pain VAS score was 7.525 ± 1.432 in the experimental group and 7.087 ± 1.799 in the control group ($P > 0.05$). The low back pain VAS scores on postoperative day 3 and at 3, 6, and 12 months postoperatively were 5.000 ± 0.987, 4.075 ± 0.997, 2.150 ± 0.834, and 1.450 ± 0.639 in the experimental group, respectively; these scores were lower than those in the control group (6.870 ± 1.572, $P < 0.05$; 4.630 ± 1.103, $P < 0.05$; 2.630 ± 1.103, $P < 0.05$; and 2.326 ± 1.034, $P < 0.05$, respectively). There was no obvious difference in the leg pain VAS scores between the two groups at all follow-up points.

The mean preoperative ODI score was 58.700% ± 19.703% in the experimental group and 61.696% ± 17.583% in the control group ($P > 0.05$). The ODI scores at postoperative months 3, 6, and 12 were 25.225% ± 5.554%, 20.150% ± 7.698%, and 16.125% ± 9.565% in the experimental group; these scores were lower than those in the control group (49.130% ± 14.805%, $P < 0.05$; 34.044% ± 15.148%, $P < 0.05$; and 29.282% ± 132.567%, $P < 0.05$, respectively).

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The mean preoperative HADS score was 14.475 ± 3.113 in the experimental group and 13.391 ± 2.824 in the control group ($P > 0.05$). However, the mean HADS scores on postoperative day 3 in the experimental group was 8.500 ± 2.000, decreasing obviously compared to the preoperative scores ($P < 0.05$). The mean postoperative HADS score on postoperative day 3 in the control group was 12.734 ± 1.949, which had not decreased significantly compared to the preoperative score ($P > 0.05$). The HADS scores in the experimental group was lower than that in the control group on postoperative day 3 ($P < 0.05$).

In the correlation analysis, the incision length was correlated to the HADS scores on postoperative day 3 ($r = 0.527$, $P < 0.05$). The HADS scores on postoperative day 3 were positively correlated with the low back pain VAS scores on the same day ($r = 0.388$, $P < 0.05$). The HADS scores on postoperative day 3were positively correlated with the ODI scores at 3-month ($r = 0.460$, $P < 0.05$), 6-month ($r = 0.429$, $P < 0.05$), and 12-month follow up ($r = 0.349$, $P < 0.05$).

Fusion rates were not significantly different between the two groups. There was no screw misplacement and loosening, infection, or delayed wound healing in either group. The cerebrospinal fluid leakage rate in the control group was higher than that in the experimental group.

Conclusion: Patients undergoing Mis-TLIF experience less anxiety and have better outcomes than those who undergo open TLIF. The lower level of anxiety experienced by patients undergoing Mis-TLIF is positively correlated with postoperative VAS and ODI scores.

Key words: Anxiety; Lumbar stenosis; Minimally invasive surgery; Spinal fusion; VAS

Introduction

Lumbar spinal stenosis (LSS) is a common type of degenerative lumbar disease, especially in the elderly. The prevalence of LSS is estimated to be 9% in the general population and is as high as 47% in people over 60 years of age[1]. Patients with LSS experience pain in the buttocks or lower extremities, with or without back pain. For patients in whom conservative treatment is ineffective, open transforaminal lumbar interbody fusion (TLIF) and minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF) are treatment options[2]. Introduced by Harms in 1982, open TLIF has become a popular and established technology[3]. With the development of minimally invasive spine technology and instruments, Mis-TLIF has gained popularity since being introduced by Foley and Lefkowitz in the early 2000s[4,5]. Both operations are widely used in clinical practice.

The purpose of treatment for LSS is to provide pain control and improve function and mobility and, thus, enhance the quality of life[6]. Both Mis-TLIF and open TLIF can significantly improve the symptoms of patients. Advantages of the TLIF approach include relatively easier access to the posterior structures, including the lamina, ligamentum flavum, and facet joints[7]. However, Mis-TLIF has demonstrated that it results in less intraoperative blood loss, shorter hospital stay and recovery time, fewer complications, and less need for postoperative narcotic use, with similar clinical outcomes and fusion rates compared with open TLIF[8–11]. Mis-TLIF remains one of the most popular surgical procedures because of surgeons' familiarity with the posterior approach anatomy[12]. Good surgical outcomes depend on both surgeons' skill and patients' good mental health. Previous studies have indicated that emotional status is associated with the quality of life of patients with lumbar spinal stenosis[6,13]. Celestin *et al.*[14] suggested that anxiety could lead to poorer outcomes after spinal surgery. However, no studies have investigated whether Mis-TLIF and open TLIF can alleviate the anxiety of patients in the perioperative period or whether patients' anxiety when undergoing these two procedures is related to their postoperative recovery.

This study investigated the following: (i) whether Mis-TLIF causes less anxiety for patients than open TLIF; (ii) whether Mis-TLIF results in better outcomes for patients than open TLIF; and (iii) whether patient anxiety is correlated with the outcomes of surgery.

Materials and Methods

Inclusion Criteria and Exclusion Criteria

The inclusion criteria were: (i) patients had been diagnosed with single-level lumbar spinal stenosis; (ii) patients had clinical signs of neurogenic claudication or severe low back pain and unilateral leg pain; (iii) there was radiographic evidence of dural sac or nerve root compression due to degenerative changes; (iv) patients were refractory to conservative treatment; (v) patients did not have congenital spinal diseases, previous surgical history, or chronic anxiety disorders; (vi) patients underwent Mis-TLIF or open TLIF; and (vii) this study was a retrospective cohort study.

The exclusion criteria were: (i) previous spinal fusion; (ii) mental impairment; (iii) systemic or neuromuscular diseases; and (iv) any subject who had previously undergone cognitive-behavioral therapy.

Patients

For this retrospective cohort study, we initially enrolled 86 patients with LSS who underwent single-segmental surgeries from January 2016 to January 2018. According to the kind of surgery, patients were divided into two groups: a control group (n = 46), for patients who underwent open TLIF surgery, and an and experimental group (n = 40), for

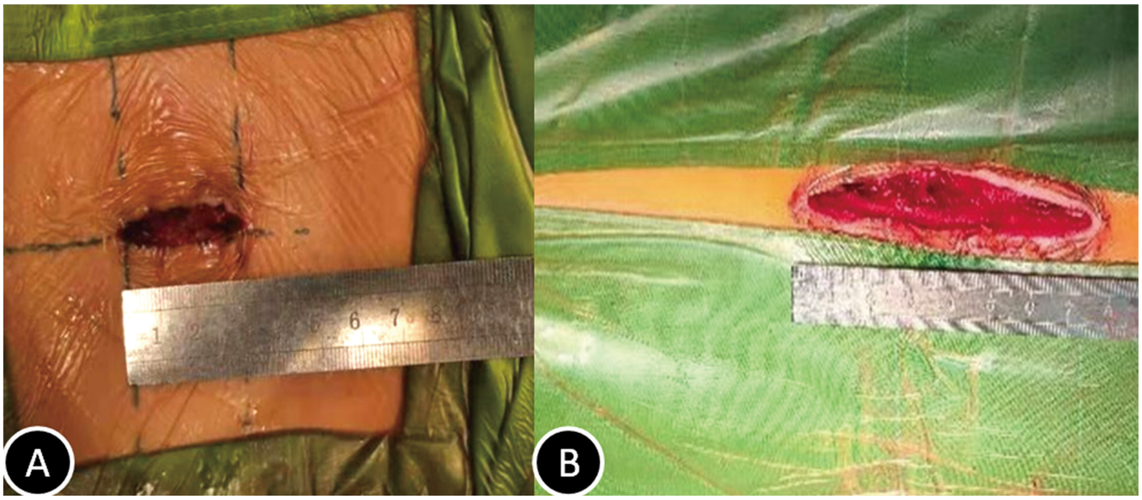

Fig. 1 (A) Our mini-open incision length was approximately 3.4 cm. (B) The incision length for open transforaminal lumbar interbody fusion (TLIF) was approximately 7.3 cm.

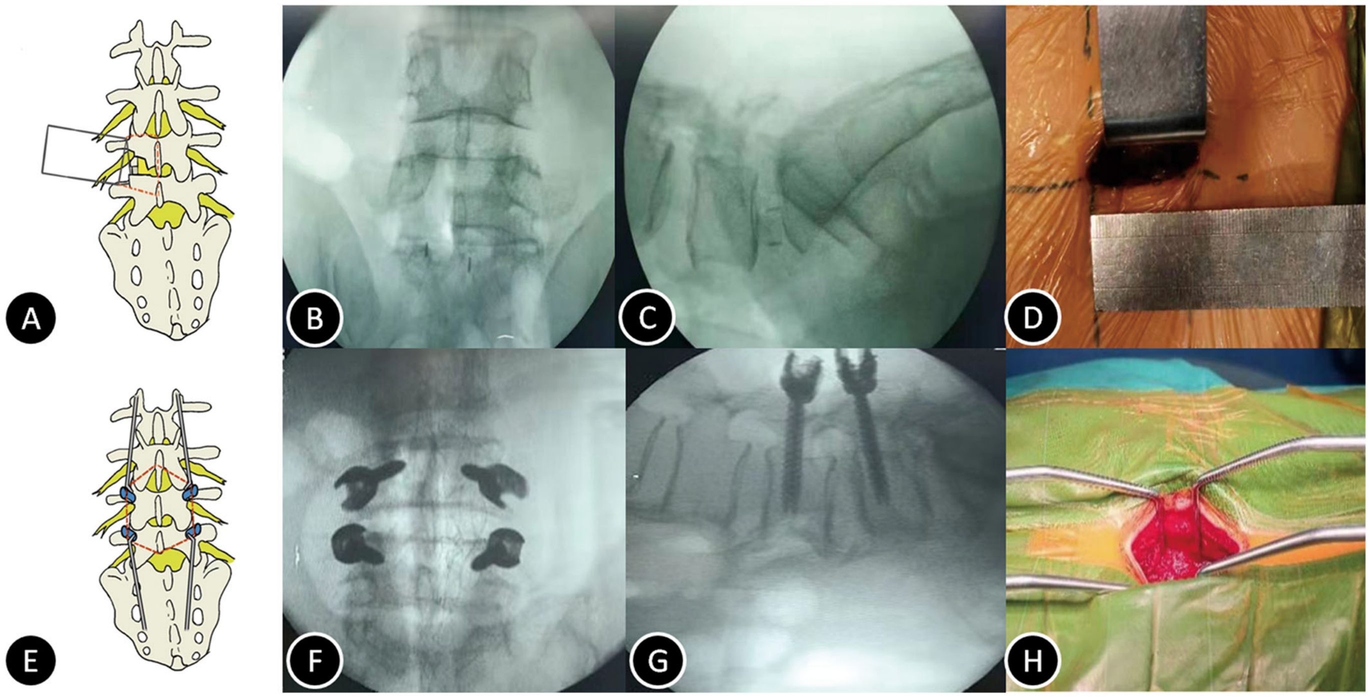

Fig. 2 (A–D) Using a single lamina retractor, the ipsilateral inferior articular process and part of the superior articular process were removed, and the intervertebral disc was cleared. Then the intervertebral cage was implanted. (E–H) Using two retractors, bilateral pedicle screws were inserted.

patients who underwent Mis-TLIF surgery. We accomplished Mis-TLIF with a mini-open incision.

Minimally Invasive Transforaminal Lumbar Interbody Fusion Surgical Procedure

After general anesthesia, the patients were placed in the prone position. The incision length was approximately 3.0 cm (Fig. 1A). Instead of using tubular retractors, we used a single lamina retractor for the whole surgical procedure. Using the single lamina retractor, we elevated and dissected the paravertebral muscles. We then removed the corresponding articular process and part of the lamina with an osteotome. After clearing the intervertebral disc, we implanted decompressed bone particles and inserted a single suitably-sized interbody fusion cage (Fig. 2A–D).

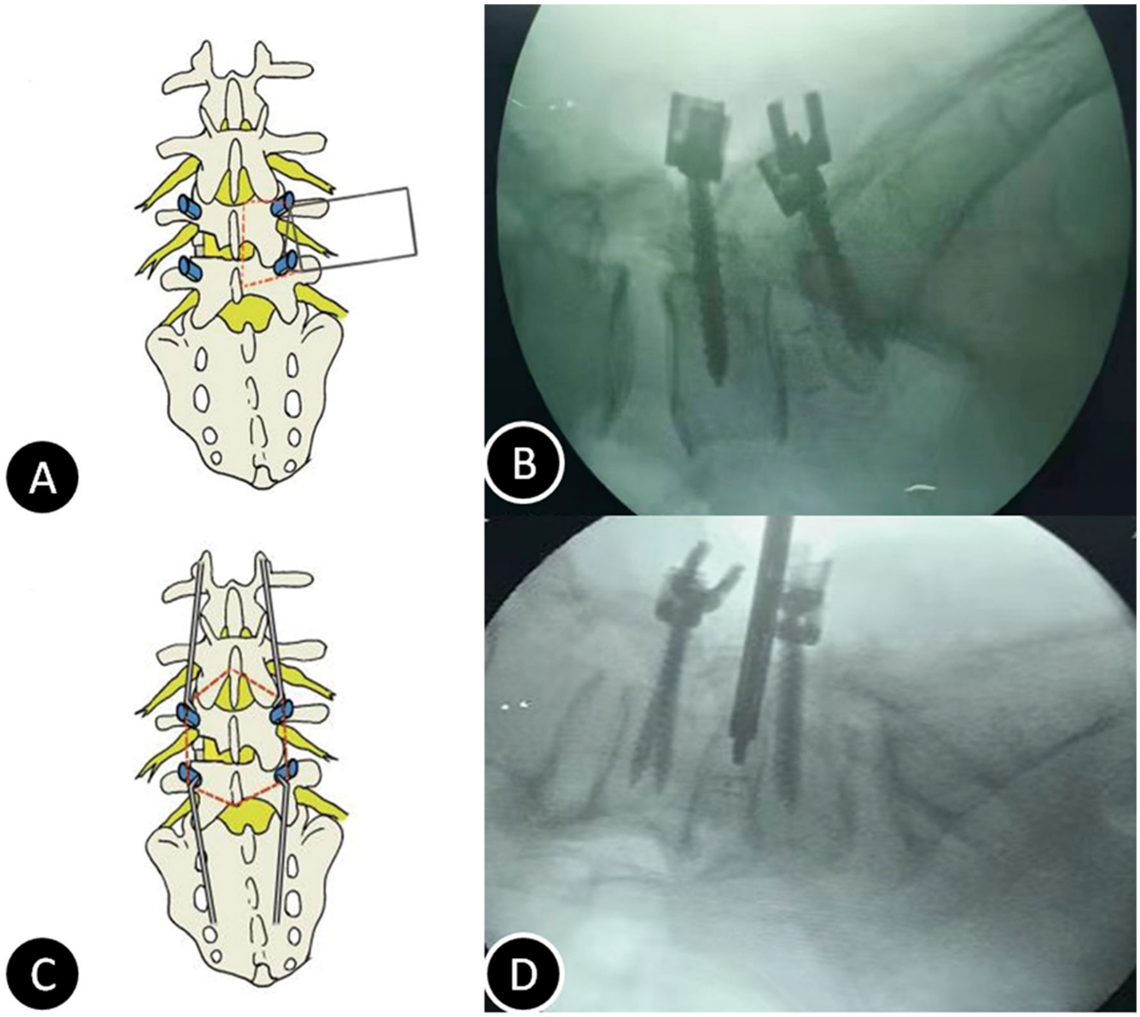

Fig. 3 (A, B) Under the exposure by a single lamina retractor, bilateral pedical screws were inserted. (C, D) Under the exposure by two retractors, the intervertebral cage was implanted.

We then inserted appropriate pedicle screws and rods (Fig. 3A,B and Fig. 4A,B). Finally, we confirmed using C-arm fluoroscopy that the internal fixation and cage were in good positions (Fig. 4C,D). The final incision for the Mis-TLIF was approximately 3.0 cm (Fig. 5A).

It truly was difficult to accomplish the surgery with the tiny incision. To ensure our surgeries were completed successfully, we performed a decompression before inserting the pedicle screws, which allowed enough space for surgeons to operate. The loupe also played an important role in ensuring sufficient views. After repeated practice, we finally mastered the technique.

Open Transforaminal Lumbar Interbody Fusion Surgical Procedure

After general anesthesia, the patients were placed in the prone position. An approximately 8.0 cm longitudinal incision was made (Fig. 1B), and the paravertebral muscles were elevated and dissected. Under the exposure by two retractors, bilateral pedicle screws were inserted (Fig. 2E–H). Then, laminotomy and unilateral facet resection were performed. Disc tissues were cleared and endplates were prepared using conventional methods. We then implanted decompressed bone particles and inserted a single suitably-sized interbody fusion cage (Fig. 3C,D). Finally, we inserted bilateral rods to connect the pedicle screws and made sure, using fluoroscopy, that the internal fixation and cage were in good positions (Fig. 4E–G). The final incision for the open TLIF was approximately 8.0 cm (Fig. 5B).

Assessment Index

The clinical outcomes were based on the size of the incision, operation time, intraoperative blood loss, visual analogue

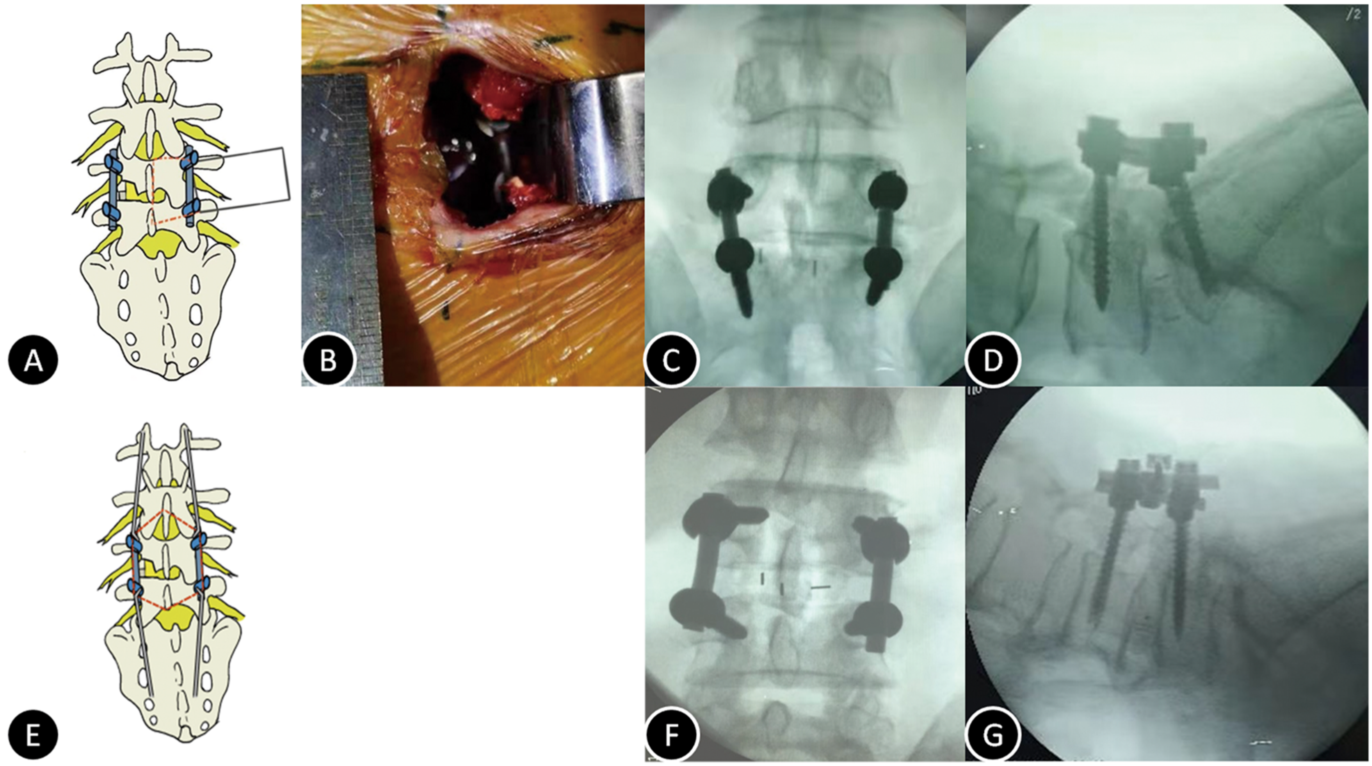

Fig. 4 (A–D) Bilateral rods were inserted and tightened under the exposure with the single lamina retractor. (E–G) Bilateral rods were inserted and tightened under the exposure with two retractors.

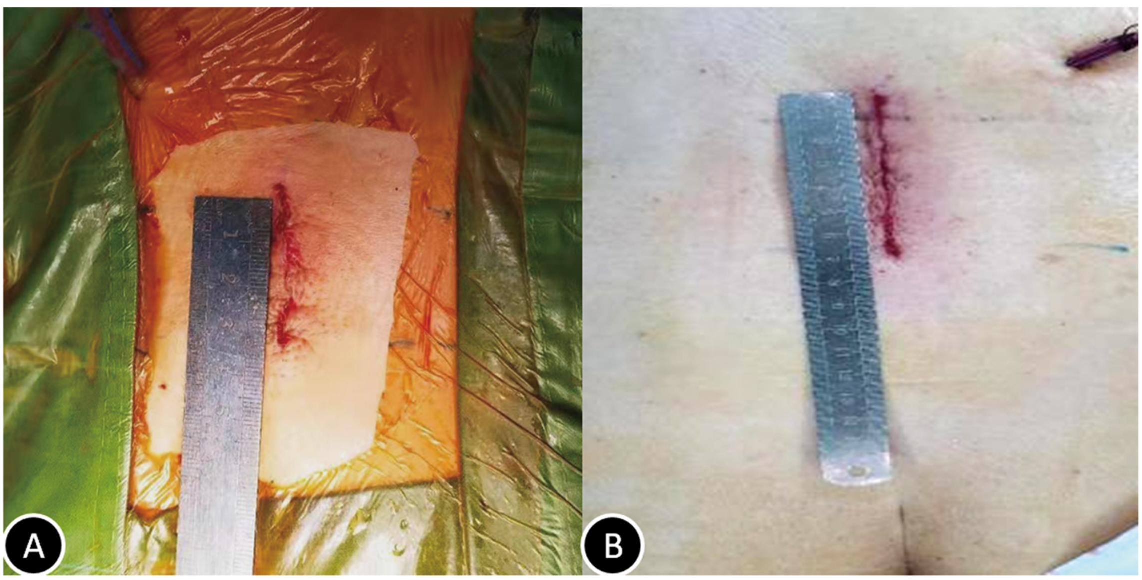

Fig. 5 (A) Final incision of minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF). (B) Final incision of open transforaminal lumbar interbody fusion (TLIF).

scale (VAS), the Oswestry disability index (ODI), hospital stay, fusion rate, and complications (screw misplacement and loosening, cerebrospinal fluid leakage, infection, and delayed wound healing). The psychological outcomes were based on the hospital anxiety and depression scale (HADS).

TABLE 1 Comparison between Mis-TLIF and open TLIF (mean ± standard deviation)

Parameters	Mis-TLIF	Open TLIF	*P*-value
Age (years)	59.1 ± 12.475	55.6 ± 9.853	0.115
Gender			
Male	19 (47.5%)	26 (56.5%)	
Female	21 (52.5%)	20 (43.5%)	0.286
Operated level			
L4–5	23 (57.5%)	27 (58.7%)	
L5–S1	17 (42.5%)	19 (41.3%)	0.911
Operation time (min)	129.00 ± 30.89	103.74 ± 36.19	0.001*
Blood loss (mL)	120.38 ± 43.57	230.33 ± 74.48	0.000*
Hospital stay (days)	4.00 ± 1.50	7.74 ± 2.70	0.000*
Incision length (cm)	3.64 ± 0.476	8.11 ± 2.406	0.000*
Low back pain VAS			
Preoperation	7.525 ± 1.432	7.087 ± 1.799	0.220
3 days postoperation	5.000 ± 0.987	6.870 ± 1.572	0.000*
3 months postoperation	4.075 ± 0.997	4.630 ± 1.103	0.017*
6 months postoperation	2.150 ± 0.834	2.630 ± 1.103	0.027*
12 months postoperation	1.450 ± 0.639	2.326 ± 1.034	0.000*
Leg pain VAS			
Preoperation	8.150 ± 1.145	8.000 ± 1.366	0.586
3 days postoperation	1.900 ± 0.632	1.848 ± 0.729	0.726
3 months postoperation	1.802 ± 0.112	1.817 ± 0.9733	0.504
6 months postoperation	1.475 ± 0.506	1.500 ± 0.506	0.820
12 months postoperation	1.325 ± 0.474	1.304 ± 0.465	0.839
ODI			
Preoperation	58.700 ± 19.703	61.696 ± 17.583	0.457
3 months postoperation	25.225 ± 5.554	49.130 ± 14.805	0.000*
6 months postoperation	20.150 ± 7.698	34.044 ± 15.148	0.000*
12 months postoperation	16.125 ± 9.565	29.282 ± 13.567	0.000*

* *P*-value < 0.05; Mis-TLIF, minimally invasive transforaminal lumbar interbody fusion; ODI, Oswestry disability index; open TLIF, open transforaminal lumbar interbody fusion; VAS, visual analogue scale.

Visual Analogue Scale

The VAS score system was used to assess low back pain and leg pain before surgery, on day 3 postoperatively, and at 3, 6 and 12 months after surgery. Subjects were asked to choose the scores that best matched their pain, from 0 (no pain) to 10 (unbearable pain) [15]. Clinical improvement was defined as preoperative and postoperative changes in VAS.

Oswestry Disability Index

The ODI was used to assess the daily activities of people with disabilities before surgery and at 3, 6, and 12 months after surgery. In the present study, nine of the ODI items were included, which assess pain intensity, personal care, weight lifting, walking, sitting, standing, sleep, social life, and travel, with the exception of sexual activity. There are six levels of dysfunction, and subjects were asked to choose the degree closest to their experience[16]. All ODI scores were added together, producing a 0%–100% scale, with 0%–20% representing minimal disability, 20%–40% representing moderate disability, 40%–60% representing severe disability, 60%–80% representing a "crippled" state, and 80%–100% representing a bedbound patient or one who is exaggerating his or her symptoms[17]. Clinical improvement was defined as preoperative and postoperative changes in ODI, and the correlations between these values were analyzed.

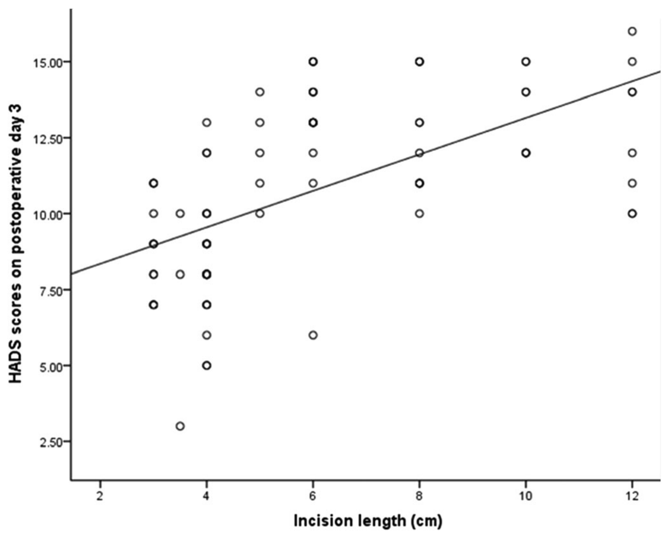

Fig. 6 Incision lengths were positively correlated with the hospital anxiety depression scale (HADS) scores on postoperative day 3.

TABLE 2 HADS scores between and within the two groups

Surgery type HADS scores	Mis-TLIF	Open TLIF	P-value
Preoperation	14.475 ± 3.113	13.391 ± 2.824	0.094
3 days postoperation	8.500 ± 2.000	12.734 ± 1.949	0.000*
P-value	0.000*	0.174	

* P-value < 0.05; HADS, hospital anxiety depression scale; Mis-TLIF, minimally invasive transforaminal lumbar interbody fusion; open TLIF, open transforaminal lumbar interbody fusion.

TABLE 3 Correlation analysis

Parameters	r-value	P-value
Incision length and HADS scores on postoperative day 3	0.527	0.000*
HADS and low back pain VAS scores on postoperative day 3	0.388	0.000*
HADS scores on postoperative day 3 and low back pain VAS scores at 3 months postoperatively	0.150	0.168
HADS scores on postoperative day 3 and low back pain VAS scores at 6 months postoperatively	0.145	0.181
HADS scores on postoperative day 3 and low back pain VAS scores at 12 months postoperatively	0.261	0.015*
HADS scores on postoperative day 3 and ODI scores at 3 months postoperatively	0.460	0.000*
HADS scores on postoperative day 3 and ODI scores at 6 months postoperatively	0.429	0.000*
HADS scores on postoperative day 3 and ODI scores at 12 months postoperatively	0.349	0.001*

* P-value < 0.05.; HADS, hospital anxiety depression scale; ODI, Oswestry disability index; VAS, visual analogue scale.

Hospital Anxiety Depression Scale
The HADS is an indicator of perioperative anxiety and depression. The HADS is a patient-oriented survey that assesses anxiety and depression on a 0–3-point scale using seven items for anxiety and seven items for depression[18]. The total scores for anxiety and depression are summed and interpreted as follows: 0–7 points, asymptomatic; 8–10 points, suspicious; and 11–21 points, definitely present. Both suspicious and symptomatic patients are considered positive for anxiety and depression.

Fusion Rate
Postoperative CT scans were obtained for all patients in the study to assess fusion status at 12 months postoperatively. Fusion was defined as evidence of bony bridges

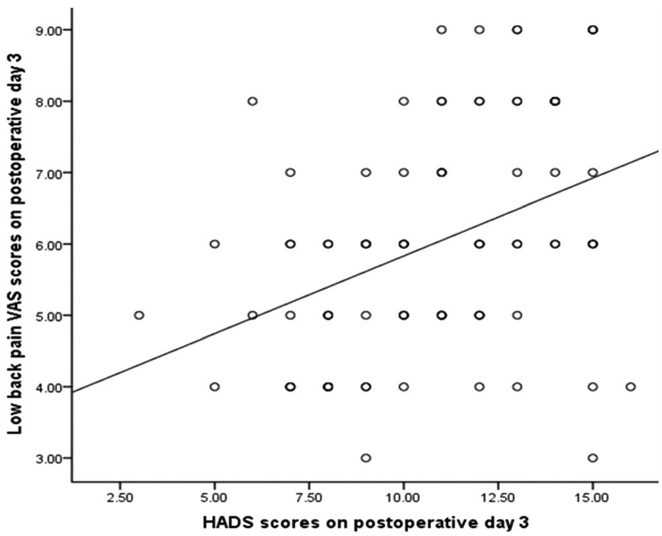

Fig. 7 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative low back pain visual analogue scale (VAS) scores at 3-day follow up.

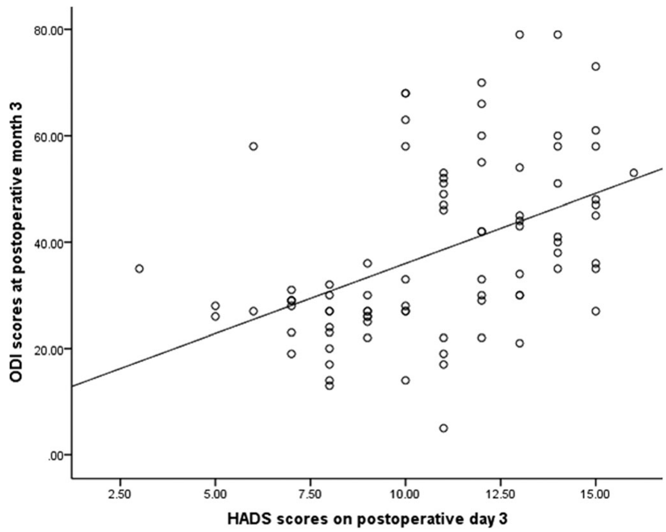

Fig. 8 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 3-month follow up.

from endplate to endplate within the cage as well as bony bridges lateral to the cage.

Subgroup Analyses
In the Mis-TLIF group, subgroup analyses were undertaken for different genders. The comparative indexes included the operation time, intraoperative blood loss, hospital stay, low back pain VAS score, leg pain VAS score, ODI score, and HADS score.

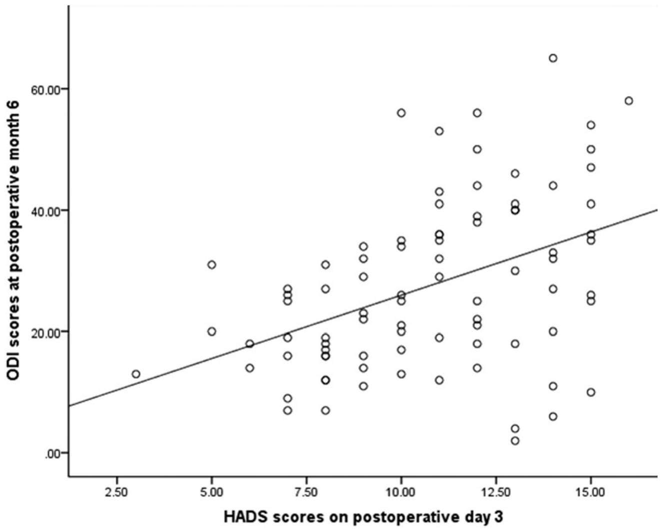

Fig. 9 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 6-month follow up.

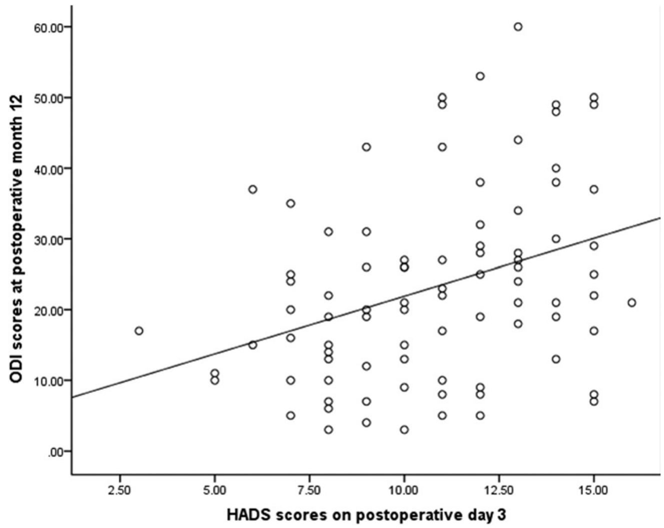

Fig. 10 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 12-month follow up.

Statistical Analysis

Patients' characteristics were summarized using means and standard deviations (SD) for continuous variables. These values were compared within and between groups. Statistical analyses, including the independent sample *t*-test, the χ^2-test, the paired sample *t*-test, and Pearson correlation analysis, were performed using IBM SPSS version 20 (IBM, Armonk, NY, USA). Statistical significance was accepted at *P*-value <0.05.

Results

Demographic and Clinical Characteristics

All patients were operated on by the same operating group in our department from January 2016 to January 2018. All patients were followed up for 12 months after surgery. In the control group, 46 patients were treated with open TLIF, including 26 men and 20 women, aged 55.6 ± 9.853 years; there were 27 patients with L4–5 lumbar stenosis and 19 patients with L5–S1 lumbar stenosis . In the experimental group, 40 patients underwent Mis-TLIF surgery, including 19 men and 21 women, aged 59.1 ± 12.475 years; there were 23 patients with L4–5 lumbar stenosis and 17 patients with L5–S1 lumbar stenosis. There was no meaningful difference in the gender, age, and operated level between the two groups ($P > 0.05$) (Table 1).

General Results

The operation time in the experimental group was 129.00 ± 30.89 (min), which was longer than that in the control group (103.74 ± 36.19, $P = 0.001$). However, the intraoperative blood loss was 120.38 ± 43.57 (mL) in the experimental group, which was less than that in the control group (230.33 ± 74.48, $P = 0.000$). The hospital stay after surgery in the experimental group was 4.00 ± 1.50 (days), which was shorter than that in the control group (7.74 ± 2.70, $P = 0.000$) (Table 1).

Incision Length

The average incision length was 3.64 ± 0.476 cm in the experimental group, which was smaller than that (8.11 ± 2.406 cm) in the control group ($P = 0.000$) (Table 1). In the correlation analysis, the length of the incision was positively correlated with the postoperative HADS score on postoperative day 3 ($r = 0.527$, $P = 0.000$) (Table 3 and Fig. 6).

Visual Analogue Scale

Before surgery, the mean low back pain VAS scores were 7.525 ± 1.432 in the experimental group and 7.087 ± 1.799 in the control group ($P = 0.220$). However, there was a noticeable difference between these two groups at all follow-up points. The low back pain VAS scores on day 3 post-surgery and at 3, 6, and 12 months after surgery were 5.000 ± 0.987, 4.075 ± 0.997, 2.150 ± 0.834, and 1.450 ± 0.639, respectively, in the experimental group; these values were lower than those in the control group (6.870 ± 1.572, $P = 0.000$; 4.630 ± 1.103, $P = 0.017$; 2.630 ± 1.103, $P = 0.027$; and 2.326 ± 1.034, $P = 0.000$, respectively).

The mean preoperative leg pain VAS score was 8.150 ± 1.145 in the experimental group and 8.000 ± 1.366 in the control group ($P = 0.586$). There was no significant difference between the two groups. The leg pain VAS scores on postoperative day 3 and at 3, 6, and 12 months postoperatively were 1.900 ± 0.632, 1.802 ± 0.112, 1.475 ± 0.506, and 1.325 ± 0.474, respectively, in the experimental group; these scores were lower than those in the control group (1.848

TABLE 4 Subgroup analysis (mean ± standard deviation)

Parameters	Male	Female	*P*-value
Incision length (cm)	3.78 ± 0.428	3.52 ± 0.475	0.085
Preoperative HADS scores	14.56 ± 3.365	14.41 ± 2.970	0.885
HADS scores on 3 days postoperation	8.39 ± 1.577	8.59 ± 2.323	0.775
Operation time (min)	124.72 ± 26.433	132.50 ± 34.322	0.435
Blood loss (mL)	126.39 ± 50.053	115.45 ± 37.951	0.437
Hospital stay (days)	3.78 ± 1.353	4.18 ± 1.622	0.404
Low back pain VAS			
Preoperation	7.177 ± 1.724	7.818 ± 1.097	0.155
3 days postoperation	4.944 ± 1.056	5.046 ± 0.950	0.752
3 months postoperation	3.778 ± 0.943	4.318 ± 0.995	0.087
6 months postoperation	2.111 ± 0.963	2.181 ± 0.733	0.793
12 months postoperation	1.667 ± 0.767	1.272 ± 0.456	0.066
Leg pain VAS			
Preoperation	8.389 ± 1.243	7.955 ± 1.046	0.586
3 days postoperation	1.889 ± 0.676	1.909 ± 0.610	0.726
3 months postoperation	1.777 ± 0.117	1.823 ± 0.107	0.504
6 months postoperation	1.500 ± 0.515	1.455 ± 0.510	0.820
12 months postoperation	1.389 ± 0.502	1.273 ± 0.456	0.839
ODI			
Preoperation	59.833 ± 18.040	57.773 ± 21.170	0.746
3 months postoperation	25.000 ± 6.297	25.409 ± 5.011	0.820
6 months postoperation	18.444 ± 7.270	21.546 ± 7.920	0.209
12 months postoperation	14.500 ± 9.679	17.455 ± 9.485	0.338

HADS, hospital anxiety depression scale; ODI, Oswestry disability index; VAS, visual analogue scale.

± 0.729, *P* = 0.726; 1.817 ± 0.9733, *P* = 0.504; 1.500 ± 0.506, *P* = 0.820; 1.304 ± 0.465, *P* = 0.839, respectively). There was also no obvious difference between these two groups at all follow-up points (Table 1). Therefore, we did not analyze the correlation between the HADS scores and leg pain VAS scores.

Oswestry Disability Index
Before surgery, the mean ODI score in the experimental group was 58.700% ± 19.703%, while the mean ODI score in the control group was 61.696% ± 17.583% (*P* = 0.457). There was no significant difference between the two groups. The ODI scores at 3, 6, and 12 months follow up were 25.225% ± 5.554%, 20.150% ± 7.698%, and 16.125% ± 9.565% in the experimental group; these scores were lower than those in the control group (49.130% ± 14.805%, *P* = 0.000; 34.044% ± 15.148%, *P* = 0.000; 29.282% ± 132.567%, *P* = 0.000, respectively) (Table 1).

Hospital Anxiety Depression Scale
The mean HADS score in the experimental group was 14.475 ± 3.113 before surgery, while the mean HADS scores in the control group was 13.391 ± 2.824 (*P* = 0.094). From the above results, it is evident that all patients felt anxious preoperatively. However, the mean HADS scores on postoperative day 3 in the experimental group was 8.500 ± 2.000, decreasing obviously compared to the preoperative scores (*P* = 0.000). The mean postoperative HADS score in the control group was 12.734 ± 1.949, which did not decrease significantly compared to the mean preoperative score (*P* = 0.174). The mean HADS score in the experimental group was lower than that in the control group on postoperative day 3 (*P* = 0.000) (Table 2).

Correlation between Visual Analogue Scale and Hospital Anxiety Depression Scale
In the correlation analysis, the HADS scores on postoperative day 3 were positively correlated with the low back pain VAS scores on the same day (*P* = 0.000) (Fig. 7). However, there were no obvious correlations with the postoperative low back pain VAS scores at 3-month (r = 0.150, *P* = 0.168), 6-month (r = 0.145, *P* = 0.181), and 12-month follow up (r = 0.261, *P* = 0.015) (Table 3).

Correlation between Oswestry Disability Index and Hospital Anxiety Depression Scale
The mean HADS score on postoperative day 3 was positively correlated with the ODI scores at 3-month (r = 0.460, *P* = 0.000), 6-month (r = 0.429, *P* = 0.000), and 12-month follow up (r = 0.349, *P* = 0.001) (Table 3, Figs 8, 9, and 10).

Subgroup Analyses
In the Mis-TLIF group, there were no differences between different genders in the operation time, intraoperative blood loss, hospital stay, low back pain VAS score, leg pain VAS score, ODI score, and HADS score. (*P* > 0.05) (Table 4).

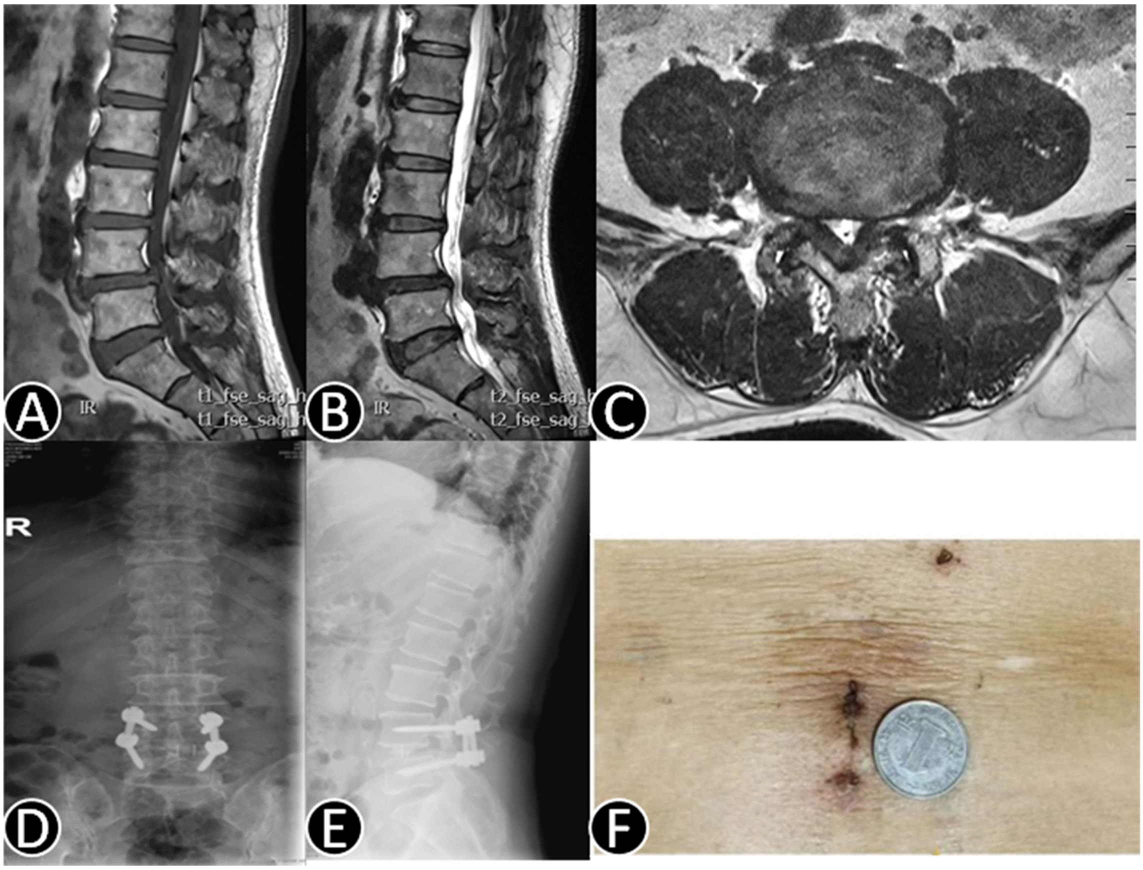

Fig. 11 A 71-year-old male patient with low back pain and left leg pain. (A) Sagittal T1-weighted, (B) sagittal, and (C) axial T2-weighted MRI of a patient with severe L4–5 lumbar stenosis. (D, E) X-ray films after surgery. (F) Mini-open incision to accomplish minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF).

Fusion Rate and Complications

The fusion rates of both groups were 100% at 12 months postoperatively. The cerebrospinal fluid leakage rate in the experimental group was 1/40 (2.5%), while the cerebrospinal fluid leakage rate in the control group was 3/46 (6.5%). There was no significant difference between the two groups ($P = 0.377$). There was no case of infection or delayed wound healing in either group. No screw misplacement or loosening occurred in the two groups.

Typical Cases

Three patients with typical single-level lumbar spinal stenosis underwent the Mis-TLIF surgery and achieved satisfactory recovery in our department (Figs 11, 12 and 13). Noting that a 1-yuan coin has a diameter of 2.5 cm, it is evident our mini-open incision length was only 3.0 cm (Figs 11 and 13).

Discussion

With the shift in the medical model from a biological to a biopsychosocial approach, the influence of psychological factors, especially anxiety, can no longer be ignored in modern therapeutics. To the best of our knowledge, this is the first study to assess the correlation between anxiety and Mis-TLIF surgery.

Incision Length

With the development of minimally invasive technology, smaller incisions are being made in patients for surgery, which appeals to patients. However, Mis-TLIF are usually performed using tubular retractors. In addition, the expensive equipment that is required and the long learning curve have limited its general development to some extent[19]. Our small incision surgery is based on the conventional surgical approach, which is more familiar to most surgeons[20,21]. Thus, we accomplished Mis-TLIF with a mini-open incision, which could preserve medical resources and reduce the learning curve. There are many differences between these two kinds of surgeries, including the incision length, operation time, blood loss, and length of hospital stay[22,23]. Our Mis-TLIF resulted in less blood loss and shorter hospital stay, reducing patient costs. From an economic perspective, most patients would prefer Mis-TLIF with a mini-open incision, to save money.

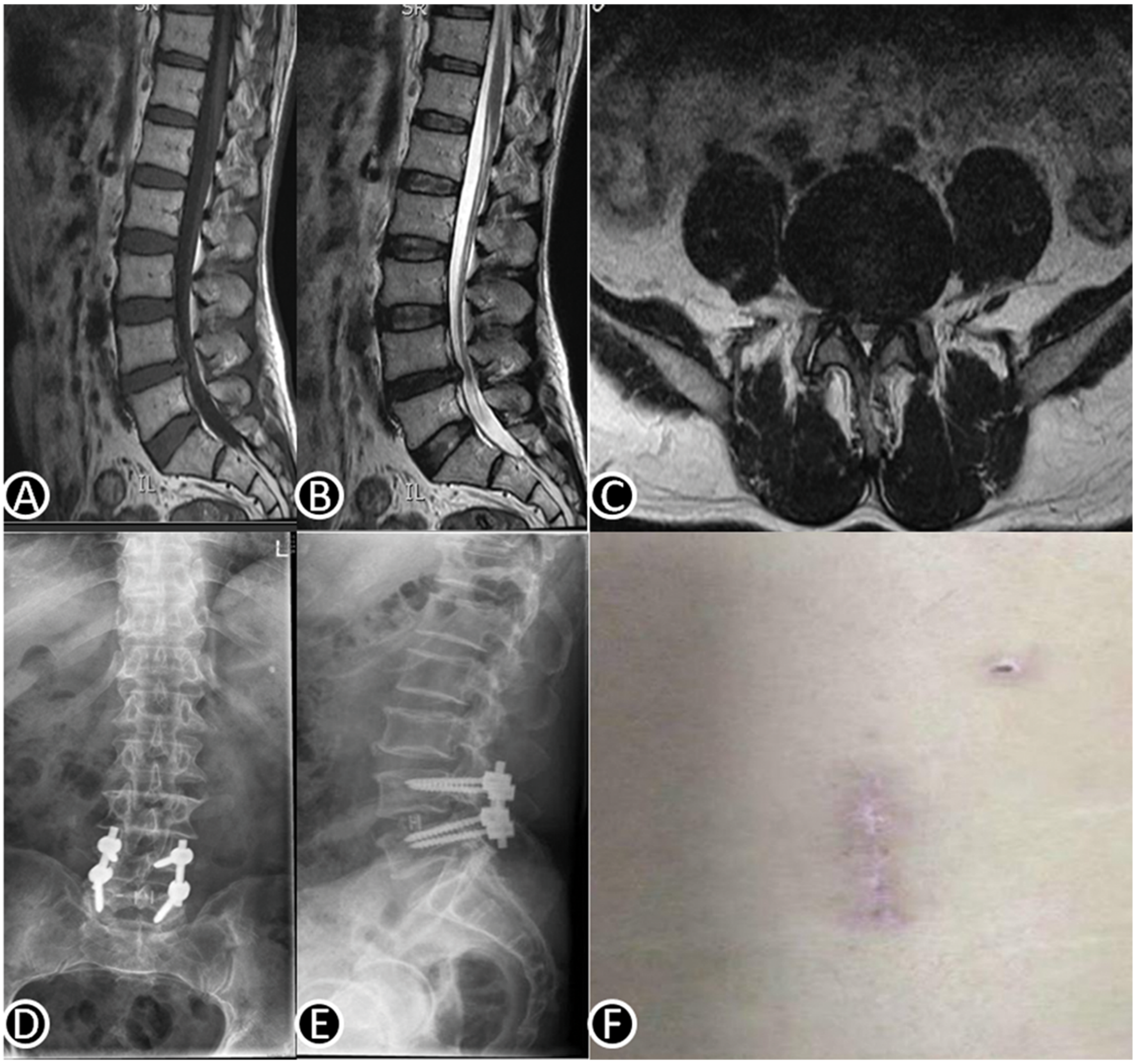

Fig. 12 A 60-year-old female patient with low back pain and right leg pain. (A) Sagittal T1-weighted, (B) sagittal, and (C) axial T2-weighted MRI of a patient with severe L4–5 lumbar stenosis. (D, E) X-ray films after surgery. (F) The incision used to accomplish minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF).

Visual Analogue Scale, Oswestry Disability Index, and Hospital Anxiety Depression Scale

In terms of low back pain VAS and ODI, our study showed that Mis-TLIF surgery resulted in better outcomes for patients than open TLIF. The minimal damage for Mis-TLIF could explain why the average low back pain VAS scores in the experimental group were lower than those for open TLIF after surgery. However, there was no significant difference in the leg pain VAS scores between the two groups, which indicated that both Mis-TLIF and open TLIF could alleviate patients' leg pain. Mis-TLIF could also assist in decompressing the nerve roots. HADS scores on postoperative day 3 in the experimental group decreased obviously compared to the preoperative scores. In addition, patients who underwent Mis-TLIF did experience less anxiety than those who underwent open TLIF after knowing their incision lengths on postoperative day 3. Postoperative HADS were positively correlated with postoperative low back pain VAS at 3 days, which demonstrated that a reduction in anxiety could alleviate patients' pain to some degree. We found that postoperative HADS were positively correlated with postoperative ODI, which means that patients with lower levels of anxiety could return to their normal lives earlier. There may be several potential explanations for this phenomenon. First, with Mis-TLIF surgery, incisions are smaller, and patients experience less anxiety compared to those undergoing open TLIF. In our correlation analysis, the incision lengths were positively correlated with the postoperative HADS scores, which indicates that the smaller the incision is, the less anxious the patient feels after surgery. Second, anxiety itself actually affects patients' physiological recovery

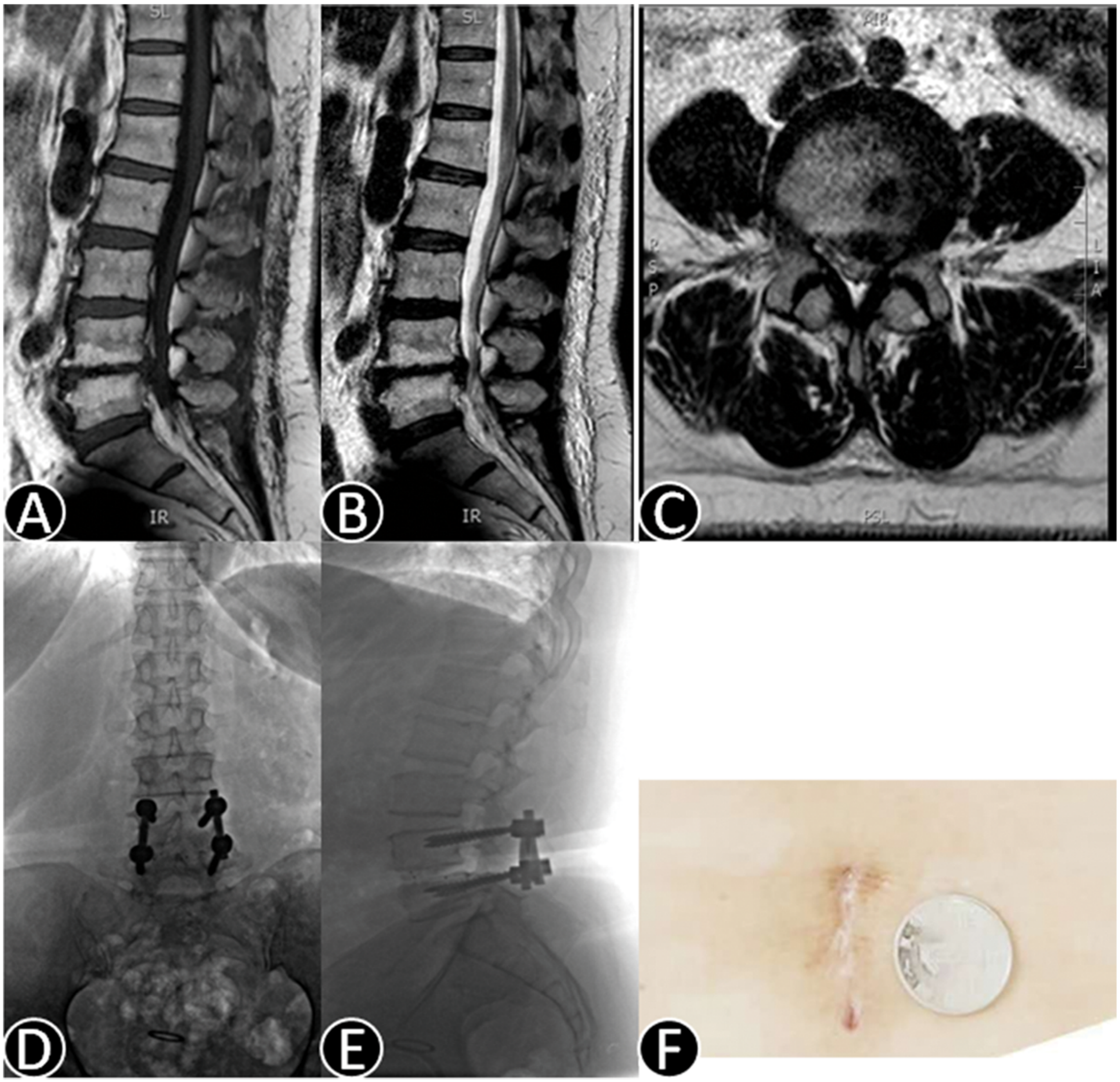

Fig. 13 A 52-year-old male patient with low back pain and left leg pain. (A) Sagittal T1-weighted, (B) sagittal, and (C) axial T2-weighted MRI of a patient with severe L4–5 lumbar stenosis. (D, E) X-ray photographs after surgery. (F) Mini-open incision to accomplish minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF).

process. Anxiety reduces patients' confidence and performance of active exercises, which means the more anxious the patient is, the slower the recovery process will be.

Influence of Anxiety

Relieving pain is an important therapeutic goal in patients with degenerative lumbar diseases, and pain should be viewed as a psychosomatic factor that bridges physical and psychological domains[24]. Daubs *et al.*[25] proposed that mental illness affects the outcomes of chronic low back pain treatment. Another study showed that increased preoperative anxiety was associated with increased postoperative pain, increased postoperative analgesia requirements, and prolonged rehabilitation and length of hospital stay for patients undergoing lumbar spine surgery (including those with lumbar spinal stenosis)[26]. Anxiety has a profound impact on patients and is often accompanied with a poor prognosis. Dobran *et al.*[27] demonstrated that anxiety was associated with a poorer clinical outcome. Lee *et al.*[18] and Dobran *et al.*[27] both found that preoperative anxiety may be related to improvement in subjective disability after surgery. In our research, it was evident that patients with LSS feel anxious before surgery. How anxiety can be relieved in patients with LSS is worth considering. Burgess *et al.*[28] suggested that preoperative education could play a positive role in such diseases. Besides preoperative education, what else can we do to alleviate patients' anxiety? The present study demonstrated that patients undergoing Mis-TLIF with a mini-open incision experienced less anxiety, and the lower level of anxiety had a positive impact on pain relief in the short term and on the daily activities of patients within 12 months postsurgery.

Fusion Rate and Complications

The fusion rates of both groups were 100% at 12 months postoperatively. With small incisions, there can be difficulties with screw and cage placement. However, there were no such issues in the present study. In addition, the success of Mis-TLIF depended on proficient skill and repetitive practice.

There was no significant difference in the cerebrospinal fluid leakage rate between the two groups. Surgeons may be concerned that cerebrospinal fluid leakage can occur when small incisions are used. The small incision did not cause this problem in the present study. On the one hand, the surgeon would be more careful when using small incisions. On the other hand, small incision surgery was performed with a microscope or a loupe, which improved the visibility of the operation area and prevented errors. There were no cases of infection or delayed wound healing in either group. Although the operation time was longer than for open TLIF, Mis-TLIF did not cause delayed incision healing or infection after surgery. In our experience, intermittently relaxing the muscle may avoid delayed wound healing after surgery. No screw misplacement or loosening occurred in either group.

Advantages of Minimally Invasive Transforaminal Lumbar Interbody Fusion

Open TLIF and Mis-TLIF are two common types of surgery for LSS. Lv *et al.*[4] found that Mis-TLIF was superior to open TLIF in terms of postoperative outcomes and could prevent paraspinal muscle atrophy during the follow-up period. In our experience, although the operation time of Mis-TLIF surgery is a little longer, patients with small incisions had significant improvements in terms of the intraoperative blood loss, hospital stay, and postoperative pain relief. In addition, there is less likelihood of injury to the posterior ligament complex of the lumbar spine, which helps to maintain the stability of the lumbar spine and promote patient recovery. Early rehabilitation also has a positive effect through alleviating the anxiety of patients and their families, and leads to a higher degree of satisfaction.

Limitations

There are several limitations of this study. First, the sample size of this study was too small. We are planning to perform further prospective research with large samples. Second, the longest follow-up time was 1 year, which should be extended in future research. Third, the patients that we enrolled did not suffer from chronic anxiety disorders. As their rehabilitation progressed, the patients' levels of anxiety gradually returned to normal. Therefore, we did not explore the relationship between long-term anxiety and patient recovery. To explore the influence of anxiety on the long-term prognosis of patients with lumbar spinal stenosis, patients with anxiety disorders as well as with lumbar spinal stenosis should be enrolled. Psychologists should be called upon to make more precise judgments.

Conclusion

Patients undergoing Mis-TLIF experience less anxiety, less low back pain, and better functional recovery than those undergoing open TLIF. The reduced anxiety as a result of Mis-TLIF is positively correlated with VAS and ODI scores. Anxiety has a profound effect on patients' recovery process and can impact their prognosis to a certain extent.

Acknowledgments

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