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Original Article

Efficacies of minimally invasive percutaneous pedicle screw fixation versus open pedicle screw fixation on the treatment of type A vertebral fractures at the thoracolumbar junction

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Abstract: Objective: To compare the efficacies of minimally invasive percutaneous pedicle screw fixation (MIPPSF) with open pedicle screw fixation (OPSF) on the treatment of type A vertebral fractures at the thoracolumbar junction. Methods: A total of 97 patients with type A vertebral fractures at the thoracolumbar junction who were admitted to our hospital were selected as the study subjects and divided into the minimally invasive group (n=42) and the open group (n=45) according to different surgical treatment. The open group received OPSF, and the minimally invasive group received MIPPSF. The efficacies of OPSF and MIPPSF were compared. Results: There was no significant difference in the duration of surgery between the two groups ($P > 0.05$). The minimally invasive group had less intraoperative blood loss and shorter incision length and postoperative hospital stay than the open group ($P < 0.05$). There were significant differences in the height and the self-angulation of the anterior edge of the injured vertebra between the two groups after surgery, at the last visit and within groups before surgery ($P < 0.05$), but there was no significant difference in the comparison within groups ($P > 0.05$). On Day 1, 3, 7 and 14 after surgery, the visual analog scale (VAS) scores in the minimally invasive group were lower than those in the open group ($P < 0.05$). The minimally invasive group exhibited higher Oswestry Disability Index (ODI) scores at month 3 and 6 after surgery and higher scores of lumbar vertebrae functions at month 1, 3 and 6 after surgery than the open group ($P < 0.05$). Conclusion: Compared with OPSF, MIPPSF is more effective in the treatment of type A vertebral fractures at the thoracolumbar junction. MIPPSF can markedly reduce trauma, intraoperative bleeding and postoperative pain, expedite the postoperative discharge, quickly alleviate dysfunction, and improve lumbar vertebrae functions.

Keywords: Vertebral fractures at the thoracolumbar junction, type A, minimally invasive percutaneous pedicle screw fixation, open pedicle screw fixation, surgery

Introduction

Thoracolumbar vertebral fractures, which do not involve spinal cord injury, are the mostly unstable fractures. Recently, due to increasing traffic and construction site accidents and an aging population, the incidence of thoracolumbar vertebral fractures is on the rise, and thoracolumbar vertebral fractures mainly occur at the thoracolumbar vertebral junction [1]. Vertebral fractures at the thoracolumbar junction in the young and middle-aged population are mostly caused by high-energy injuries. However, because the elderly population has osteoporosis to varying degrees, the elderly are prone to vertebral fractures at the thoracolumbar junction even if slight injuries, such as falls, occur [2, 3].

According to previous studies, the severity of fracture injury is assessed using multiple classification systems, and it is highly recommended to implement surgical treatment as soon as possible upon the accurate determination of the surgical indications. However, there is no consensus as to which conservative method is more effective in surgery [4, 5]. There are two types of surgical methods, namely, open pedicle screw fixation (OPSF) and minimally invasive percutaneous pedicle screw fixation (MIPPSF). Long-term clinical practices suggest that there are some shortcomings in OPSF, such as long-term postoperative chronic pain in the back and waist, and even local muscle necrosis and fibrous scarring [6]. With the progressive advances in medical technologies, the concept of minimally invasive surgery has been extensively developed. There are multiple surgical options available clinically for the treatment of vertebral fractures at the thoracolumbar junction [7]. MIPPSF makes up for the deficiencies of OPSF. Using MIPPSF, the postoperative spinal canal diameter, the maintenance of postoperative vertebral body height and the correction of postoperative kyphosis angle are more satisfactory to physicians and patients [8].

In this study, the difference in efficacy between MIPPSF and OPSF for the treatment of patients with type A vertebral fractures at the thoracolumbar junction were compared and analyzed.

Materials and methods

Data information

A total of 97 patients with type A vertebral fractures at the thoracolumbar junction who were admitted to our hospital from January 2019 to December 2019 were selected as the study subjects and divided into the minimally invasive group (n=42) and the open group (n=45) according to different surgical options. The open group received OPSF, and the minimally invasive group received MIPPSF. Inclusion criteria: Patients aged between 18 and 70 years; who were confirmed with type A1, A2 and A3 vertebral fractures at the thoracolumbar junction by imaging examination; who complied with the surgical indications of operation; and who understood the surgical method and risks. Patients voluntarily signed the study consent form before the 6 months of postoperative follow-ups. This study was performed with the approval of ethical examination by the Hospital Ethics Committee of The Second Affiliated Hospital of Xi'an Jiaotong University. Exclusion criteria: Patients whose injured vertebra and adjacent segments had been treated by surgery previously; those with multiple fractures; who were complicated with important organ injuries; who were complicated with vertebral bone tumor; who were complicated with nervous system injuries; and who were unable to complete all follow-ups were excluded from this study.

Methods

Open group: The patients received general anesthesia and endotracheal intubation, and were placed in the prone position, with flexion of legs and elevation of the chest and abdomen. The injured vertebra was located using an X-ray machine, and the surface of pedicle of vertebral arch of the injured vertebra and upper and lower vertebral bodies were projected and marked. Manual reduction was performed on the surface of injured vertebral body, disinfection and towel laying were conducted routinely, and a longitudinal incision was made in the midline of the back of spine according to the marks on the surface of vertebral body. After the incision, the paraspinal muscles were stripped subperiosteally with an electrotome (along the spinous process and the vertebral plate), and the sacrospinous muscles were pushed outward. During the surgery, electrocoagulation was performed to stop bleeding, and the injured vertebral body, adjacent vertebral bodies and the upper and lower articular processes of the injured vertebral body were fully exposed. The apex of the herringbone spine was selected as the needle insertion point, and the positioning needle was inserted after the open vertebra was opened. When the X-ray examination revealed that the positioning needle was in a satisfactory position, the positioning needle was pulled out, tapping was performed along the open vertebra previously opened, and a suitable pedicle screw of vertebral arch was then placed. The satisfactory position of pedicle screw of vertebral arch was determined with the X-ray machine. The suitable connecting rods were pre-bent to a certain radian, and were placed through both sides. The tail cap was installed and locked *in situ*. The positions of all internal fixators were determined and the satisfactory vertebral reduction was confirmed with an X-ray machine. Wounds were thoroughly washed using normal saline, drainage tubes were left on both sides, and wounds were sutured layer by layer routinely.

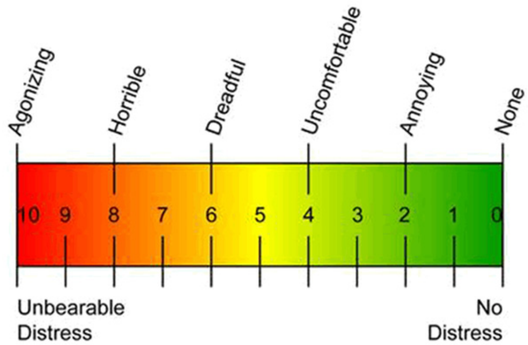

Figure 1. VAS scoring scale.

Minimally invasive group: Before disinfection and towel laying, the procedures were the same as those in open group. A longitudinal incision with a length of about 2.0 cm was made at the marked site on the surface of pedicle of vertebral arch of the injured vertebra and the upper and lower adjacent vertebral bodies, and the muscle and fascia were punctured to the cortex of the outer lower edge of the pedicle of vertebral arch using the puncture cone. After the correct puncture was confirmed with an X-ray machine, the puncture cone was screwed into the pedicle of vertebral arch. The cross-section and sagittal puncture cone were properly adjusted using an X-ray machine to 1 cm from the anterior edge of vertebral body. The needle core of the puncture cone was taken out, the hollow sleeve was placed along the puncture needle sleeve to spread the soft tissue slowly, the guidewire was inserted under the puncture needle sleeve, and then the position of the guidewire was determined with an X-ray machine. The guidewire and the outermost expansion sleeve were kept, and other hollow expansion sleeves were removed. The hollow tapping was taken using the guidewire to implement tapping, and then the tapping was taken and screwed into the hollow pedicle screw of vertebral arch using the guidewire. The remaining 5 pedicles of vertebral arch were treated using the aforementioned method, and all hollow pedicle screws of vertebral arch in vertebral body were confirmed with an X-ray machine. A suitable connecting rod was selected, and was inserted using the nail tail of the hollow screw on both sides, the position of the rod was properly adjusted until it was satisfactory, and then the tail cap was screwed through the hollow screw, and locked *in situ*. The subsequent procedures were the same as those in open group.

Observation indices

General data: The gender, age, injured vertebral segments, fracture classification, and surgical interval were collected in the two groups.

Surgical conditions: The duration of surgery, incision length, postoperative hospital stay and the amount of intraoperative blood loss were recorded in the two groups.

Imaging results: The height of the anterior edge of the injured vertebra: the reference was the standard lateral X-ray film of thoracolumbar segment, and the height of the anterior edge of the injured vertebra was obtained with an X-ray machine. The height of postoperative injured vertebra: the height of anterior edge of injured vertebra obtained in the lateral X-ray film at the first visit after surgery. The last height: the height of the anterior edge of the injured vertebra obtained in the lateral X-ray film at the last visit. The self-angulation of the injured vertebra: the comparative angle of the longitudinal or vertical lines intersecting the upper and lower endplates of the injured vertebra obtained in the standard lateral X-ray film of thoracolumbar spine. The self-angulation of postoperative injured vertebra: the angle obtained in the lateral X-ray film at the first visit after surgery. The self-angulation of the last injured vertebra: the angle obtained in the lateral X-ray film at the last visit.

Degree of pain: Before surgery and on Day 1, 3, 7 and 14 after surgery, the degree of pain of injured vertebra was assessed using visual analogue scale (VAS) [9], and the assessment was performed using the level scale, with 11 numbers from 0 to 10. A greater number indicates a more severe degree of pain (**Figure 1**).

Lumbar vertebrae functions: Before surgery, at 1 week after surgery, and at 1, 3 and 6 months after surgery, the efficacy for the treatment of lumbar vertebrae diseases was assessed using Japanese Orthopaedic Association (JOA) scores [10]. The highest score was 29 points, with 14 points for the daily activities, 6 points for clinical examination and 9 points for conscious symptoms. A higher score indicates a better lumbar vertebrae function.

Dysfunction: Before surgery and at 3 and 6 months after surgery, the assessment was

Table 1. Comparison of general data between the two groups ($\overline{x}$ ± s)/[n (%)]

Data		Minimally invasive group (n=45)	Open group (n=42)	t/X^2	P
Gender	M	27 (60.00)	25 (59.52)	0.002	0.964
	F	18 (40.00)	17 (40.48)		
Age (years)		42.36±15.89	43.61±16.34	0.362	0.719
Time from admission to surgery (d)		4.16±1.34	4.27±1.47	0.365	0.716
Injured vertebral segment	T11	5 (11.11)	4 (9.52)	0.849	0.421
	T12	2 (4.44)	3 (7.14)		
	L1	21 (46.67)	20 (47.62)		
	L2	17 (37.78)	15 (35.91)		
Fracture classification	A1	13 (28.89)	11 (26.19)	1.268	0.385
	A2	17 (37.78)	13 (30.95)		
	A3	15 (33.33)	18 (42.86)		

performed using Oswestry Dability Index (ODI) [11]. There were 10 questions: sex life, lifting, sitting, social activities, self-care, standing, traveling, pain, sleeping and walking. All patients were scored from 0 to 5 points, with a total score of 0 to 50 points. A higher score indicates a more serious dysfunction.

Statistical analysis

Statistical analysis was performed using SPSS 23.0. Enumeration data were expressed as [n (%)] and detected using chi-aquared test. Measurement data were expressed as ($\overline{x}$ ± sd), and detected using *t* test. The intra-group and inter-group multi-point comparisons were analyzed using analysis of variance (ANVOA) and F test. The graphs were made using Graphpad Prism 8. P < 0.05 indicated a statistically significant difference.

Results

General data

There was no statistically significant difference in the ratio of male and female patients, the segments of injured vertebra, the types of fracture, the mean age and the surgical intervals between the minimally invasive group and the open group (P > 0.05) (**Table 1**).

MIPPSF improves the quality of surgery

The incision length was (10.16±1.68) cm in the minimally invasive group and (17.45±3.62) cm in the open group. The duration of surgery was (168.46±40.82) min in the minimally invasive group and (176.62±42.34) min in the open group. The amount of blood loss was (90.62±34.59) ml in the minimally invasive group and (121.43±40.62) ml in the open group. The postoperative hospital stay was (6.89±3.62) d in the minimally invasive group and (10.51±4.49) d in the open group. There was no significant difference in the duration of surgery between the open group and the minimally invasive group (P > 0.05). Compared with the open group, the minimally invasive group had shorter incision length and postoperative hospital stay and less amount of intraoperative blood loss (P < 0.05) (**Figure 2**).

Both MIPPSF and OPSF improve the imaging results

There was no significant difference in the height of the anterior edge of the injured vertebra between the minimally invasive group and the open group before surgery (P > 0.05). The height of the anterior edge of the injured vertebra between the two groups at the postoperative and last visits were higher than those within groups before surgery (P < 0.05), but there was no statistically significant difference in the comparison within groups (P > 0.05). There was no significant difference in the self-angulation of injured vertebrae between the minimally invasive group and the open group before surgery (P > 0.05). The self-angulations of injured vertebrae between the two groups at postoperative and last visits were lower than those within groups before surgery (P < 0.05), but there was no statistically significant within groups (P > 0.05) (**Figure 3**).

MIPPSF relieves degree of pain

There was no significant difference in VAS scores of injured vertebrae between the mini-

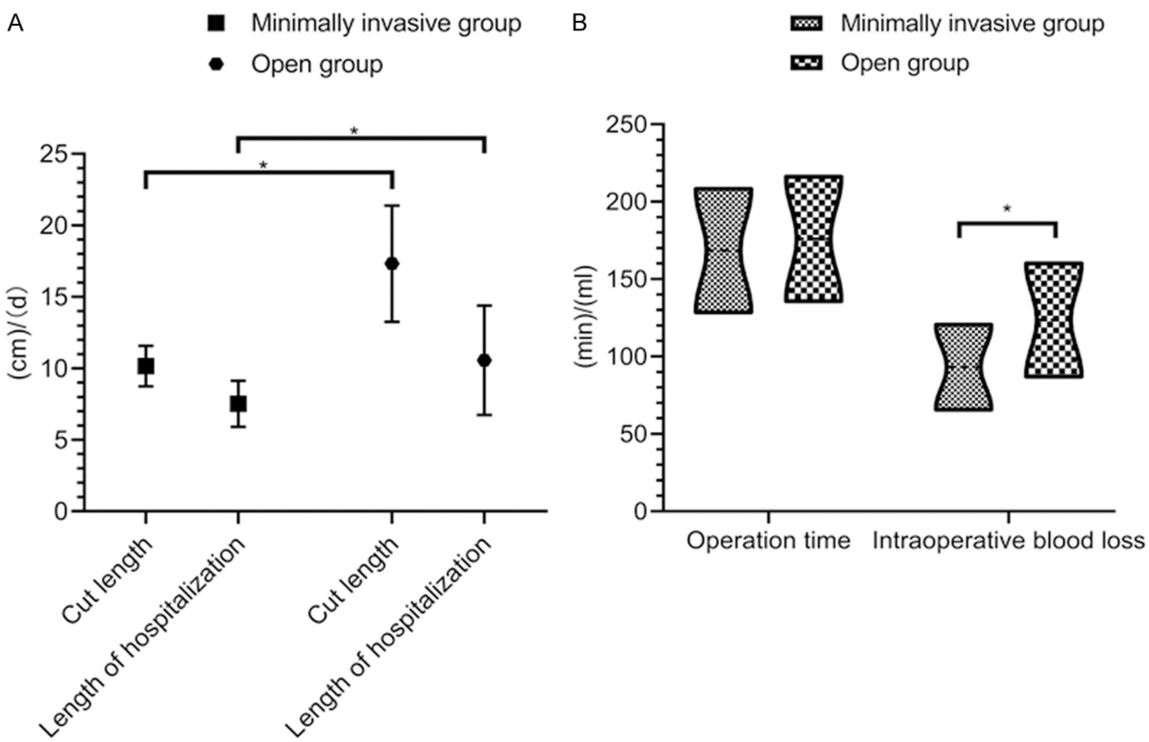

Figure 2. Comparison of surgical conditions between the two groups. Compared with that in open group (A), the incision length and the hospital stay in minimally invasive group were markedly shorter (*P* < 0.05). There is no significant difference in the duration of surgery (B) between open group and minimally invasive group (*P* > 0.05). Compared with that in open group (B), the amount of intraoperative blood loss in minimally invasive group was significantly reduced (*P* < 0.05). * indicates *P* < 0.05.

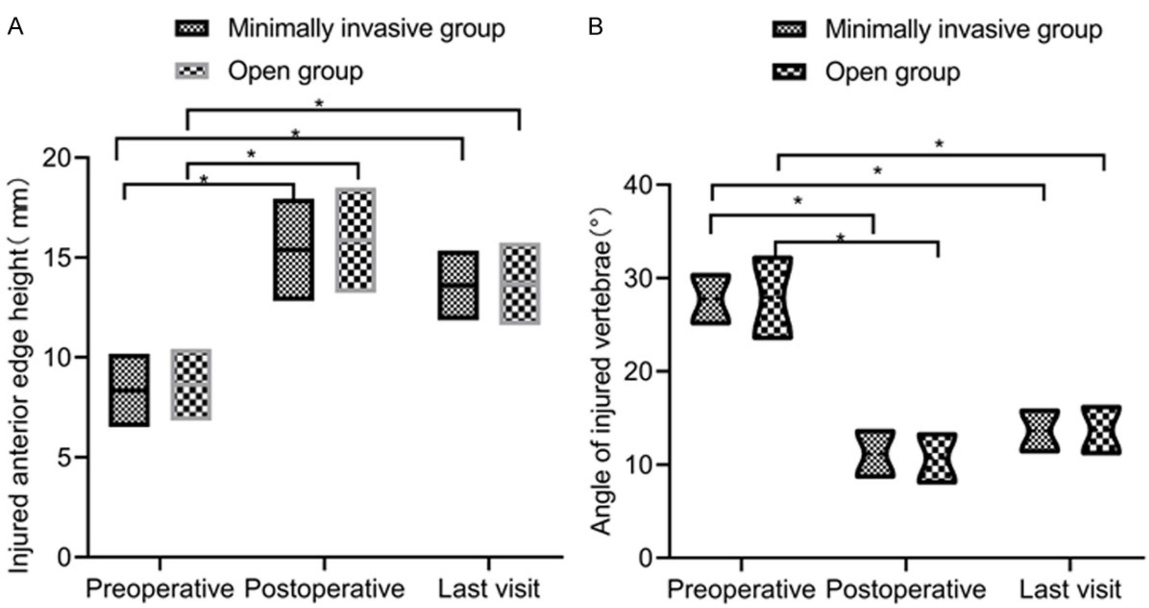

Figure 3. Imaging results. There was no significant difference in the comparison of the height of anterior edge of injured vertebra (A) and the self-angulation of injured vertebra (B) between open group and minimally invasive group before surgery (*P* > 0.05). There was no significant difference in the height of anterior edge of injured vertebra (A) and the self-angulation of injured vertebra (B) between open group and minimally invasive group after surgery and at the last visit (*P* > 0.05). Compared with the height of the anterior edge of the injured vertebra (A) and the self-angulation of the injured vertebra (B) within groups before surgery, there were statistically significant differences between minimally invasive group and open group after surgery and at the last visit (*P* < 0.05). * indicates *P* < 0.05.

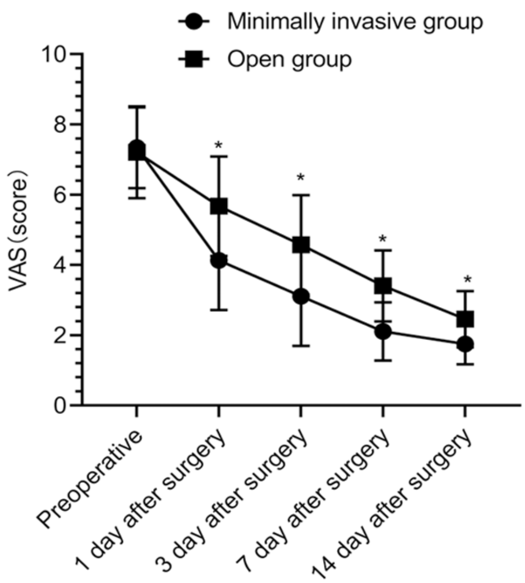

Figure 4. Degree of pain. There was no significant difference in the comparison of the preoperative VAS scores between the open group and the minimally invasive group ($P > 0.05$). The VAS scores in the minimally invasive group were lower than those in the open group on Day 1, 3, 7 and 14 after surgery ($P < 0.05$). * indicates $P < 0.05$.

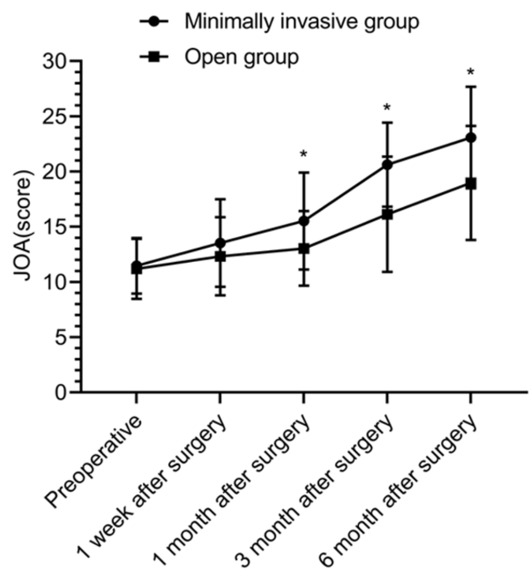

Figure 5. Lumbar vertebrae functions. There was no significant difference in the scores of lumbar vertebrae functions between the open group and the minimally invasive group before surgery ($P > 0.05$). There was no significant difference in the scores of lumbar vertebrae functions between the open group and the minimally invasive group at 1 week after surgery ($P > 0.05$). The scores of lumbar vertebrae functions in the minimally invasive group were higher than those in the open group at 1, 3 and 6 months after surgery ($P < 0.05$). * indicates $P < 0.05$.

mally invasive group and the open group before surgery ($P > 0.05$). There were statistically significant differences in VAS scores of injured vertebrae between the minimally invasive group on Day 1 after surgery and within groups before surgery ($P < 0.05$), but there was no significant difference in VAS scores of injured vertebrae between the minimally invasive group and the open group on Day 1 after surgery ($P > 0.05$). The VAS scores of injured vertebrae in both groups on Day 3, 7 and 14 after surgery were lower than those within groups before surgery ($P < 0.05$). The VAS scores of injured vertebrae in the minimally invasive group after surgery were lower than those in the open group on Day 1, 3, 7 and 14 after surgery ($P < 0.05$) (**Figure 4**).

MIPPSF improves lumbar vertebrae functions

There was no significant difference in the scores of preoperative lumbar vertebrae functions between the minimally invasive group and the open group before surgery ($P > 0.05$). The scores of preoperative lumbar vertebrae functions between the two groups at 1 week after surgery were higher than those before surgery, but there was no significant difference within groups ($P > 0.05$). The scores of lumbar vertebrae functions in both groups at 1, 3 and 6 months after surgery were higher than those within groups before surgery, and the differences in the comparisons within groups were significant ($P < 0.05$) (**Figure 5**).

MIPPSF alleviates dysfunctions

There was no significant difference in ODI scores between the minimally invasive group and the open group before surgery ($P > 0.05$), but there were significant differences in the comparisons between the two groups before surgery and within groups at 3 and 6 months after surgery ($P < 0.05$). The ODI scores in the minimally invasive group were lower than those in the open group at 3 and 6 months after surgery ($P < 0.05$) (**Figure 6**).

Discussion

Type A thoracolumbar fractures are vertebral compression fractures (VCFs), type A3 thoracolumbar fractures are burst fractures, type

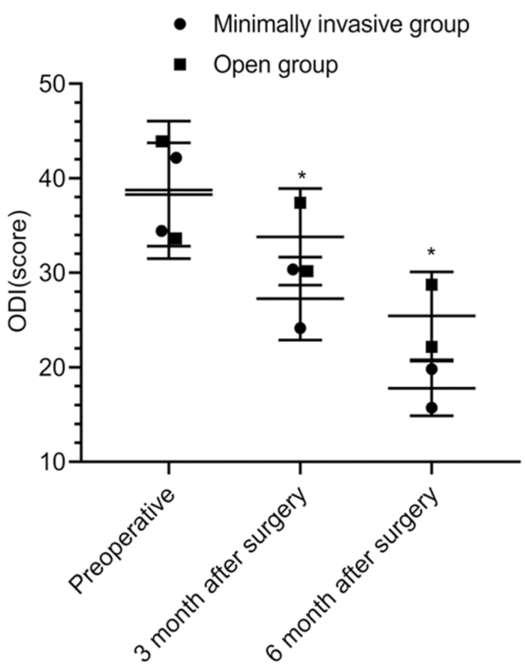

Figure 6. Dysfunction. There was no significant difference in the scores of dysfunction between the open group and the minimally invasive group ($P > 0.05$). The scores of dysfunction in the minimally invasive group were lower than those in the open group at 3 and 6 months after surgery ($P < 0.05$). * indicates $P < 0.05$.

A2 thoracolumbar fractures are split fractures, and type A1 thoracolumbar fractures are compression fractures [12, 13]. In the rates of whole-body fracture, the incidence of spinal fractures is approximately 5%. There is obvious local pain, and the pain is more intense as a result of the changes in body position. However, the patients basically do not have nervous system injury [14]. A small number of patients with vertebral fractures protruding into the spinal canal suffer from neurological impairment, easily elevating the risks of dysuria and defecation and the incidence of lower limb movement disorders and sensory disturbances [15, 16].

The results of this study revealed that the minimally invasive group had shorter incision length, less amount of intraoperative blood loss and earlier postoperative discharge. Compared with those before surgery, the height of the anterior edge and the self-angulation of the injured vertebra in the two groups were improved after surgery, but there was little difference between the two groups after surgery, indicating that OPSF and MIPPSF can effectively improve the injured vertebra. However, when MIPPSF was implemented, there was shorter incision length and less intraoperative blood loss, indicating a safer and more effective surgery. Therefore, the patients can be discharged earlier after surgery. The aforementioned result has confirmed that compared with OPSF, MIPPSF can reduce bleeding and trauma and expedite the postoperative recovery [17]. Similar studies have suggested that MIPPSF for the treatment of thoracolumbar vertebral fractures can relieve the impact on paraspinal muscles and shorten the time required for postoperative recovery [18]. On Day 1, 3, 7 and 14 after surgery, the degree of pain of injured vertebra in the minimally invasive group was lower than that in the open group ($P < 0.05$), exhibiting that MIPPSF can greatly relieve the degree of pain of injured vertebra. MIPPSF leads to the shorter incision length, resulting in a simpler and more convenient treatment of the incision after surgery, and a reduced risk of pain caused by surgery. A study has revealed that MIPPSF is a feasible option to mitigate the pain in the affected site after surgery [19].

At 1, 3 and 6 months after surgery, the lumbar vertebrae function in the minimally invasive group were improved, and the dysfunctions were improved at 3 and 6 months after surgery ($P < 0.05$). This suggests that compared with OPSF, MIPPSF can significantly improve the postoperative lumbar dysfunction and the lumbar vertebrae functions of patients with thoracolumbar vertebrae fractures. Studies have shown that patients receiving MIPPSF for the treatment of thoracolumbar vertebrae fractures can avoid wearing protective equipment for a long time, have an earlier starting time for out of bed activities, and receive functional rehabilitation exercise as soon as possible. Therefore, MIPPSF is very suitable for young and middle-aged patients [20]. This study revealed that an earlier starting time for out of bed activities and rehabilitation exercise after MIPPSF facilitated a fast recovery of the patients' lumbar vertebrae functions.

According to the aforementioned results, it can be concluded that patients who undergo MIPPSF have a shorter incision length, reduced risk of infection, less amount of bleeding, shortened duration of surgery, and improved postoperative pain and compliance for postoperative rehabilitation exercise, and the patients revealed no strong discomfort. MIPPSF is mainly performed in the muscle space of the multifidus muscle, and the muscle insertions and the fascia on lumbar back muscle basically are not damaged. Therefore, the risks of long-term intractable chronic low back pain after surgery can be reduced using MIPPSF [21, 22]. Another study has suggested that compared with OPSF, MIPPSF has reduced duration of surgery and postoperative hospital stay as well as less intraoperative bleeding, and has improved effects in maintaining spinal stability [23]. However, based on the previous clinical experience and the surgical practices in this study, there are some difficulties in implementing MIPPSF, primarily including the need for multiple fluoroscopy during surgery that leads to radiation damage, difficulty in grasping during the puncture process that prolongs the duration of surgery and elevates the surgical risks [24]. There are difficulties in positioning the pedicle of vertebral arch and determining the needle insertion point [25]. Failure to accurately determine the locking sequence of screw tail cap may affect fracture reduction [26]. Therefore, although there is a satisfactory efficacy using MIPPSF, highly qualified physicians with a wealth of clinical experience are required. The physicians must be well familiarized with every surgical step and accurately perform the operations, so as to minimize the surgical risks and maximize the surgical efficacy.

In summary, compared with OPSF, MIPPSF is more effective in the treatment of type A vertebral fractures at the thoracolumbar junction. MIPPSF can markedly reduce trauma, intraoperative bleeding and postoperative pain, expedite the postoperative discharge, quickly alleviate dysfunction, and improve lumbar vertebrae function. However, there are some shortcomings in this study, such as insufficient subjects enrolled, only patients with type A vertebral fractures at the thoracolumbar junction enrolled, so with the lack of comprehensiveness in the analysis of the study results, and a short postoperative follow-up period, may have biased the results obtained. Therefore, future studies with a larger sample size and a longer period should be performed, so as to obtain more scientific study conclusions.

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Disclosure of conflict of interest

None.

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