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A Comparison of the Mini-Open Wiltse Approach with Pedicle Screw Fixation and the Percutaneous Pedicle Screw Fixation for Neurologically Intact Thoracolumbar Fractures

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Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: The thoracolumbar AO type A3 fracture is an incomplete burst fracture, which affects one vertebral body endplate. The objective of this study was to determine which of two minimal invasive techniques was more suitable for A3 fractures based on clinical and radiographic results.

Material/Methods: We studied 112 patients with A3 subtype fractures without neurological deficits. A total of 63 patients received percutaneous pedicle screw fixation (PPSF), and 49 patients were treated using mini-open Wiltse approach with pedicle screw fixation (MWPSF). The clinical outcomes, surgery-related results, and the pre-operative and post-operative radiological findings were compared between the two groups.

Results: The length of incision, intra-operative blood loss, post-operative hospitalization time, visual analog score (VAS), Oswestry disability index (ODI), and accuracy rate of pedicle screw placement were compared between the PPSF and MWPSF groups, with no significant differences found ($p>0.05$). However, the vertebral body angle (VBA) and Cobb's angle in the MWPSF group was much better than in the PPSF group ($p<0.05$). The operating time and C-arm exposure time of the MWPSF group were significantly lower than the PPSF group ($p<0.05$). The operative and post-operative costs of the PPSF group were significantly higher than the MWPSF group ($p<0.05$).

Conclusions: Our study found no significant differences in some clinical outcomes between the two groups. Both treatments were safe and effective for A3 subtype fractures. Nevertheless, given the radiation exposure, reduction of kyphosis, special equipment required, learning curve and hospitalization costs associated with PPSF, we concluded that MWPSF was a better choice for A3 subtype fractures.

MeSH Keywords: Lumbar Vertebrae • Spinal Fractures • Surgical Procedures, Minimally Invasive • Thoracic Vertebrae

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Background

Almost 60% of spinal fractures occur in the thoracolumbar region [1,2]. Internal fixation after decompression is the most common technique for cases involving neurological injuries. However, for neurologically intact cases, the traditional approach increases intra-operative blood loss and prolongs hospital stay. Moreover, extensively detached paraspinal muscles can cause soft tissue ischemia, myophagism, and even post-operative chronic pain [3–7]. In 1968, Wiltse first described the paraspinal sacrospinalis-splitting approach to treat lumbar spinal fractures [8], and in 1984, Magerl first reported the use of PPSF in the lumbar spine [9]. In 1995 and 2001, respectively, Mathews et al. [10] and Foley et al. [11] suggested improved percutaneous techniques. As doctors obtained a deeper understanding of the concept of minimally invasive surgery, PPSF and MWPSF have become widely used, with advantages including less intra-operative blood loss, a shorter hospital stay, and less damage to paraspinal muscles [12,13]. Because the starting and ending points of paraspinal muscles are not damaged in MWPSF and PPSF, these procedures both can drastically reduce peri-operative complications, post-operative muscle atrophy, and back pain [14,15]. To the best of our knowledge, no study comparing the percutaneous and Wiltse approaches for pedicle screw fixation in the treatment of thoracolumbar AO type A3 fractures has been performed. The A3 subtype is an incomplete burst fracture, which only affects one vertebral body endplate. In the present study, we aimed to compare the clinical and radiological outcomes of using PPSF and MWPSF to treat thoracolumbar AO type A3 fractures.

Material and Methods

Before the surgery, the doctor introduced the advantages and disadvantages of surgical treatment and conservative treatment in detail to the patient and their family. The treatment method was chosen voluntarily by patient. This retrospective study used the following inclusion criteria: 1) the types of fractures were single thoracolumbar (T10-L2) AO type A3 fractures; 2) no neurological deficits were present; 3) the patients ranged in age from 18 to 60 years; and 4) all patients underwent posterior surgery after being injured for one to seven days. The exclusion criteria were as follows: 1) pathologic or osteoporotic fractures; 2) other significant injuries were present; 3) earlier surgery had been performed at the fracture site; and 4) patients presented with other diseases, such as osteoarthritis or cervical myelopathy, that could significantly influence daily life.

Patient population

We reviewed 112 cases of single-segment, neurologically intact thoracolumbar (T10–L2) AO type A3 fractures from January 1, 2013 to December 31, 2014 in patients who met the aforementioned criteria. A total of 63 patients (48 males and 15 females), with a mean age of 41.7±12.1 years (range, 19 to 60 years), underwent PPSF. There were 49 patients (36 males and 13 females), with a mean age of 42.1±12 years (range, 21 to 60 years), who underwent MWPSF. The demographic data of the cases are presented in Table 1.

Clinical outcomes

Both groups were compared in terms of the length of incision, operation time, intra-operative blood loss, C-arm exposure time, post-operative hospitalization time, operative and post-operative costs, and perioperative complications. The

Table 1. Description of the patient population.

Characteristic	PPSF group	MWPSF group	P
No. of cases	63	49	...
Age, mean ±SD, yr	41.7±12.1	42.1±12.0	0.86
Sex (Male/Female)	48/15	36/13	0.74
BMI (Body Mass Index)	21.6±1.6	21.1±1.8	0.12
Level of fracture			
T11	13	9	0.76
T12	14	14	0.44
L1	23	19	0.81
L2	13	7	0.38

PPSF – percutaneous pedicle screw fixation; MWPSF – mini-open Wiltse approach with pedicle screw fixation; SD – standard deviation.

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visual analog scores (VAS), vertebral body angle (VBA), and Cobb's angle were evaluated at pre-operation, the fifth day after surgery, and the final follow-up. Oswestry disability index (ODI) scores were evaluated at pre-operation and the final follow-up. The accuracy of the pedicle screw placement was based on the evaluation of post-operative computed tomography (CT) scans.

Operative techniques

PPSF group

Before the procedure, the patient was placed in a prone position after general anesthesia, and silicone pads were used to support the chest and pelvis. The kyphosis of the fractured vertebral body was corrected by hyperextension. Before routine sterilization, we used C-arm (Brivo OEC 850, GE, Fairfield, CT, USA) located above and below the pedicles of the fractured vertebrae on the skin, where the instrumentation would be fitted. We used the C-arm to obtain antero-posterior (AP) and lateral posterior pictures of the thoracolumbar area to make sure the smaller locational catheter was through the incision at the marked point. The guide wire was then inserted into the catheter. The fascia and soft tissue were separated using a series of sequential dilators. A self-tapping, cannulated pedicle screw with an appropriate length and diameter was inserted into the vertebra through the guide wire under the protection of the outside catheter. All procedures were under C-arm fluoroscopic image guidance. Using the aforementioned steps, the other five screws were put in sequentially and then the guide wire and protective catheter were removed. Two rods of appropriate lengths were inserted through the upper incision and the paraspinous muscles to reach the caudal pedicle screw, and then the rods were fixed using cranial bolt heads. The rods could also be lengthened to restore the height of the fractured vertebra, if necessary, and the cranial bolt heads were tightened subsequently. Bipolar forceps were used to control any wound hemorrhaging. The incisions were closed after irrigation, and no drainage was installed.

MWPSF group

The same pre-operative procedure as used in the percutaneous approach was used for the MWPSF group. The positions of the fractured vertebrae were determined and marked using the C-arm. After routine sterilization and placement of the drapes, the surgeon made an approximate 8 cm midline incision at the surgical level and then separated the subcutaneous tissue and the longissimus and multifidus muscles to expose the space around the pedicle entry point. Six pedicle screws were implanted sequentially by free hand, and AP and lateral fluoroscopy images were taken to ensure that the screws were placed in their ideal positions. Two rods of appropriate lengths were implanted, and the height of the vertebral body was restored by lengthening the rods appropriately. The locations of the implants were again confirmed by C-arm images. The incisions were irrigated and then closed with intermittent sutures; no drainage was installed.

Statistical analysis

Variables with continuous data are reported as the means and standard deviations. Independent sample *t*-tests and the χ^2 test were used to compare the outcomes between the two groups. These statistical tests were 2-tailed, and $p<0.05$ was considered statistically significant. The statistical analyses were conducted using SPSS version 19 (SPSS Inc., Chicago, IL, USA).

Results

All patients had follow-up appointments after an average period of 15.8±3.8 months (6~24 months) for the PPSF group and 14.6±5.4 months (6~24 months) for the MWPSF group, with no statistically significant difference between the two groups ($p=0.19$). No significant differences existed between the two groups in terms of age, sex, body mass index (BMI), and disease duration. Ninety-seven patients who achieved bone union prior to the final follow-up underwent a second operation to remove the implants.

Between the two groups, there was no significant difference ($p>0.05$) in blood loss, length of incision, or post-operative hospitalization time. The mean surgery times were 72.5±7.7 minutes (55~95 minutes) in the PPSF group and 63.3±8.9 minutes (50~80 minutes) in the MWPSF group, which fared slightly but significantly better ($p<0.05$). The C-arm exposure times were 16.3±2.6 seconds (13.6~21.6 seconds) and 4.8±1.7 seconds (3.2~9.6 seconds), respectively, with the PPSF group obtaining significantly more cumulative exposure to radiation ($p<0.05$). The operative and post-operative costs of the PPSF group were 59,346.2±1,129.3 CNY, and those of the MWPSF group were 51,692.3±1,289.0 CNY, which was significantly lower ($p<0.05$). The accuracy rate of pedicle screw placement was 96.56% (365/378) in the PPSF group and 97.28% (286/294) in the MWPSF approach, with no significant difference between the two groups ($p=0.60$). No vertebral endplate was broken by a screw, and no complications such as blood vessel or nerve injuries, were found (Table 2, Figure 1).

In each of the two groups, there were significant differences in the pre-operative and post-operative vertebral body angle (VBA), Cobb's angle, VAS, and ODI; the VBA and Cobb's angle were significantly better in the MWPSF group, as shown by the data (Table 3).

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Table 2. Clinical findings.

	PPSF group	MWPSF group	P
Operation time, mean ±SD, min	72.5±7.7	63.3±8.9	P<0.05
Blood loss, mean ±SD, mL	54±17.2	55.3±20.8	0.36
C-arm exposure time, mean ±SD, seconds	16.3±2.6	4.8±1.7	P<0.05
Length of incision, mean ±SD, cm	8.0±1.6	7.8±1.2	0.47
Postoperative hospital stay, mean ±SD, days	4.2±0.7	4.1±1.0	0.54
Operation and post-operation costs, mean ±SD, CNY	59,346.2±1129.3	51,692.3±1289.0	P<0.05
Accuracy rate of pedicle screw placement, %	96.56 (365/378)	97.28 (286/294)	0.60

PPSF – percutaneous pedicle screw fixation; MWPSF – mini-open Wiltse approach with pedicle screw fixation; SD – standard deviation.

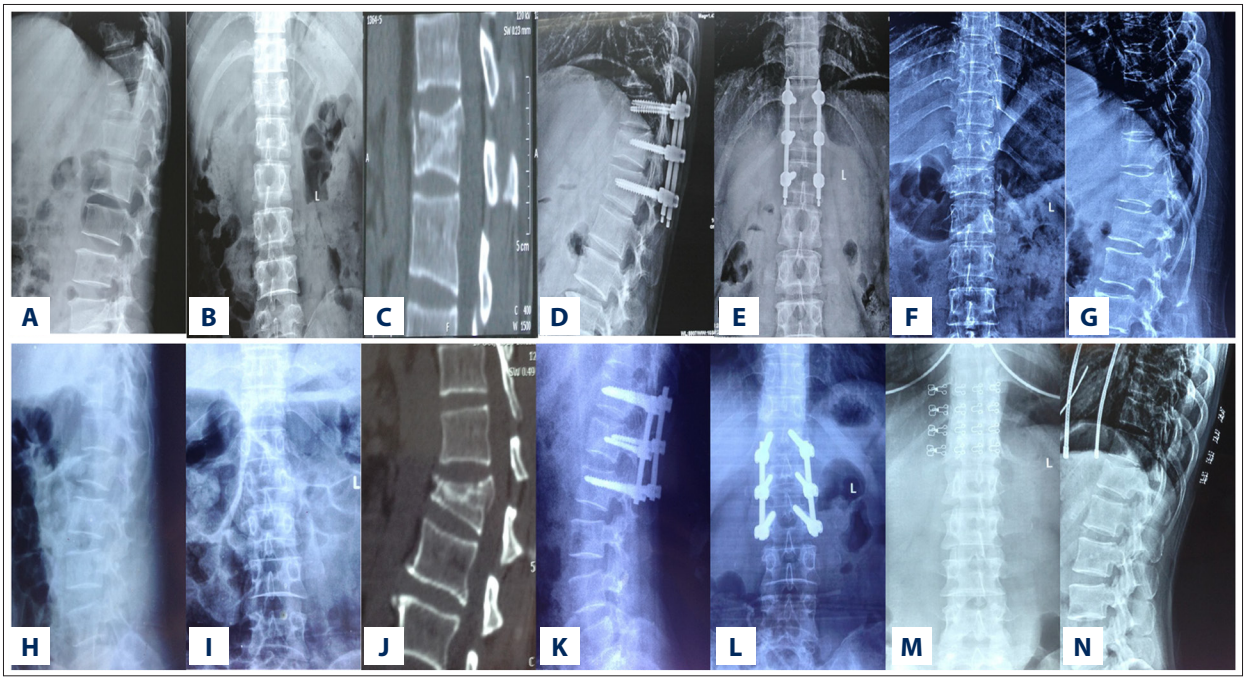

Figure 1. The mini-open Wiltse approach with pedicle screw fixation (**A–G**) and percutaneous pedicle screw fixation (**H–N**). Pre-operative radiographical images: lateral view (**A, H**) and anterior-posterior view (**B, I**). CT scans: sagittal view (**C, J**). Post-operative radiographical images: lateral view (**D, K**) and anterior-posterior view (**E, L**). Final follow-up radiographical images: anterior-posterior (**F, M**) view and lateral view (**G, N**).

One case in the MWPSF group exhibited delayed wound healing after operation due to the presence of type 2 diabetes, and three cases exhibited delayed wound healing in the PPSF group; these incisions healed smoothly after active treatment in a local hospital. During the follow-up, there were no reports of infection, pneumonia, deep vein thrombosis, implant failure, or other complications.

Discussion

The conventional posterior approach is considered a classical method for thoracolumbar fracture treatment with satisfactory clinical outcomes. However, the traditional approach damages the ending point of the multifidus muscle bound, which affects the function of the muscles and limits waist torsion, leaving the patient unable to stand by themselves and thus increasing the risk of bedsores and other complications [12,13,16,17]. In comparing post-operative MRIs taken after the conventional posterior approach and PPSF, Kim et al. [13] found that the pre-surgery and post-surgery cross-sectional

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Table 3. Comparison of VAS, ODI, VBA and Cobb' s angle between the two groups.

		PPSF group	MWPSF group	P
Preoperative, mean ±SD	VAS	7.0±0.9	6.9±0.8	0.54
	ODI	91.5±2.4	92.1±2.3	0.18
	VBA, °	21.4±7.8	22.9±8.5	0.33
	Cobb's angle, °	20.1±8.3	22.0±9.1	0.25
The 5th day after surgery, mean ±SD	VAS	2.5±0.7	2.7±0.9	0.19
	VBA, °	9.2±6.9	6.2±5.1	0.01*
	Cobb's angle, °	6.4±7.1	3.5±5.1	0.02*
Final follow-up, mean ±SD	VAS	0.7±0.6	0.6±0.9	0.48
	ODI	3.2±1.7	3.6±1.5	0.20
	VBA, °	9.9±7.1	6.7±5.5	0.01*
	Cobb's angle, °	7.0±6.9	3.9±5.6	0.01*

VAS – visual analog score; ODI – oswestry disability index (version 2) on a 0% to 100% scale; VBA – vertebral body angle; PPSF – percutaneous pedicle screw fixation; MWPSF – mini-open Wiltse approach with pedicle screw fixation; SD – standard deviation.
* There was statistical difference between the two groups (P<0.05).

areas of the multifidus muscle showed no statistically significant differences in the PPSF group, but in the conventional posterior group, muscle atrophy was significant. Therefore, in recent years, minimally invasive techniques have been widely used in spine surgery, especially in thoracolumbar fractures without neurological deficits [18–20].

In this study, we assessed the use of short-segment six pedicle screw fixation combined with intermediate screw fixation in both groups. Previous studies reported that the short-segment method could obtain satisfactory results for unstable thoracolumbar burst fractures without fusion [21]. In a prospective and randomized study, the nonfusion group showed better peri-operative parameters [22]. Our results showed that the short-segment fixation of thoracolumbar fractures without fusion was an effective method. In terms of safety, it has been reported that deviations of approximately 3% in the accuracy rates of percutaneous pedicle screw insertion is unacceptable [23]. Our accuracy results were 96.56% (365/378) for the PPSF group and 97.28% (286/294) for the MWPSF group. No complications were caused by the misplacement. The results were better in the MWPSF group, but this difference was not significant. We inferred that the pedicle screws were placed under direct vision in the MWPSF group.

In the current study, the pre-operative and post-operative VBA and Cobb's angles showed significant differences in both groups. We found that instrument operation combined with hyperextended position after general anesthesia could correct kyphosis. However, we found in the MWPSF group, VBA and Cobb's angles were improved much better than in the PPSF group, especially in cases of serious compression fracture. We think skin and muscle could have hamper the diaplastic operation in the PPSF group, and compared with the MWPSF group, diaplastic instrument was more indirect in the PPSF group. In both groups, the post-operative VAS and ODI values were significantly improved compared to the pre-operative values. In our previous experience, for some appropriate cases, we have found that these two minimally invasive approaches are the best choices. Li et al. [12] reported that the Wiltse approach is similar to the conventional method in terms of the restoration of the vertebral body height, improvement of Cobb's angle, and the accuracy rate of screw placement with the added advantages of shorter post-operative hospital stays (3.4 days versus 9.1 days) and less intra-operative bleeding (34.5 mL versus 144.8 mL). Wu et al. [24] found the same results, and some additional studies on percutaneous pedicle screw fixation have reported similar conclusions [19,25,26]. The post-operative hospitalization time showed no significant difference between the PPSF group (4.2±0.7 days) and the MWPSF group (4.1±1.0 days) (p=0.54), though both groups showed significantly better results compared to the conventional method described in previous studies. Lumbar multifidus intramuscular adipose tissue has been shown to be associated with back pain [27]. Kramer et al. [28] analyzed 32 cases using electromyography (EMG) and noted the importance of protecting the soft tissue to avoid long-term back pain after operation. The starting and ending points of the paraspinal muscles were retained in our procedures, which could help patients with early functional exercises. However, there were no significant

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differences in the above indexes and intra-operative blood loss between the PPSF group and the MWPSF group ($p>0.05$), suggesting that these two techniques are similarly effective, minimally invasive surgical techniques for thoracolumbar fractures.

In this study, we found that the operation time of the PPSF group (72.5±7.7 minutes) was significantly higher than that of the MWPSF group (63.3± 8.9 minutes) ($p<0.05$). We thought that manipulating the C-arm multiple times during operation would significantly increase the operation time; our study showed the differences in the C-arm exposure times between the PPSF group (16.3± 2.6 seconds) and the MWPSF group (4.8±1.7 seconds). In some studies, PPSF has been shown to rely more on intra-operative fluoroscopy, and as a result, the surgeons and patients received higher doses of radiation [29,30]. In our study, the surgeons were encouraged to wear multiple safeguards. However, the heavy plumbic suit not only increases the burden on the surgeon but also influences the surgical procedures. PPSF has a steeper learning curve and requires a certain degree of surgical experience [19,31]. Rahamimov et al. [32] compared the PPSF approach to conventional methods, finding that PPSF demanded more techniques and required more time. However, we thought that obtaining proficiency in MWPSF was much easier. Every percutaneous pedicle screw needs an approximately 1.5 cm incision, and in the present study, the mini-open via Wiltse approach was shown to need only an 8 cm midline incision. Unexpectedly, we found that the lengths of incisions were 8.0±1.6 cm (6.0~10 cm) in the PPSF group and 7.8±1.2 cm (6.5~9.5 cm) in the MWPSF group; thus, the PPSF group did not show less trauma ($p=0.47$) [33]. MWPSF conforms to the minimally invasive concept that is now advocated. The more intensive radiation exposure for the patient and a steeper learning curve for PPSF were not investigated in previous studies [34]. In the present study, we also compared the operative and post-operative costs of the PPSF group (59,346.2±1,129.3 CNY) and the MWPSF group (51,692.3±1,289.0 CNY), finding a significant difference between them ($p<0.05$). We found that post-operative hospitalization time and treatment prescriptions were similar between the two groups; thus, the main reason for the cost difference was that more expensive implants were used in the PPSF group.

The Wiltse approach also has several advantages. 1) The accurate separation of the muscle compartment can guarantee vascular completeness so that the soft tissue remains intact. Compared with traditional open surgery, this approach could significantly reduce the surgical bleeding, helping patients to perform functional exercises earlier and avoid long-term back pain. 2) PPSF requires special equipment, and all of the staff involved in the surgery must be familiar with how it works. By contrast, MWPSF can be completed using conventional surgical instruments. 3) Finally, compared to the hollow pedicle screw, the hardness and other biomechanical properties of the solid pedicle screw have been proven in many long-term studies in recent decades.

In this study, one patient with type 2 diabetes in the MWPSF group experienced delayed wound healing after the operation. In the PPSF group, three cases exhibited delayed wound healing. These patients were transferred to a local hospital after their disease stabilized; their incisions healed smoothly after active treatment. In our experience, surgery can affect the blood glucose levels of diabetic patients. Guzman et al. [35] reported that among patients who underwent lumbar spine surgery, diabetic patients had a higher risk of complications, such as surgical site infection, than nondiabetic patients. We therefore suggest that the surgeon should pay close attention to preventing peri-operative complications in diabetic patients. For the three cases in the PPSF group, we thought that the cause of the delayed wound healing might have been that the skin and soft tissue were stretched by the dilator for an excessively long time during the operation.

Though our study describes short-term follow-up research, 97 patients (86.6%) who achieved bone union prior to the final follow-up had the implant removed at the final follow-up. Therefore, we inferred that the radiographic results of MWPSF were similar to those of the conventional approach in terms of the long-term follow-up. However, our study had an important limitation. This was a single-center retrospective study, so there is a need for further multicenter prospective and random trials to verify our findings.

Conclusions

Our study revealed that there were no significant differences in some of the clinical outcomes between PPSF and MWPSF. PPSF and MWPSF were both safe and effective for the treatment of thoracolumbar AO type A3 fractures. Nevertheless, considering the reduction of kyphosis, radiation exposure, requirements for special equipment, learning curve, and hospitalization costs associated with PPSF, we concluded that MWPSF was a better choice for thoracolumbar AO type A3 fractures.

Conflict of Interest

None.

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