


CLINICAL ARTICLE

Comparison of the Wiltse Approach and Percutaneous Pedicle Screw Fixation Under O-arm Navigation for the Treatment of Thoracolumbar Fractures

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Objectives: The aim of this study was to evaluate the clinical outcomes of the Wiltse approach and percutaneous pedicle screw placement under O-arm navigation for the treatment of thoracolumbar fracture.

Methods: We enrolled a total of 54 patients with neurologically intact thoracolumbar fracture who received minimally invasive treatments between October 2014 and October 2018 in this retrospective study. Among these, 28 patients (22 males and six females, with a mean age of 48.6 ± 9.6 years) were treated with pedicle screw fixation through the Wiltse approach (WPSF), and another 26 (15 males and 11 females, with a mean age of 45.7 ± 10.6 years) received percutaneous pedicle screw fixation under O-arm navigation (OPSF). Statistical methods were used to perform a detailed comparison of clinical outcomes, radiologic findings, and complications between the two groups obtained pre-operatively, postoperatively, and at last follow-up.

Results: All patients underwent surgery successfully and finished a follow-up of more than 12 months. No serious complications, such as infection, blood vessel injury, or spinal cord or nerve root injury occurred. Visual analog scale (VAS) scores, Oswestry disability index (ODI) scores, local Cobb angle (LCA), vertebral wedge angle (VWA), and R value were notably improved after surgery, though there was no clear discrepancy between the groups at each time point ($P > 0.05$). During the follow-up period, no patients developed neurological impairment or implant-related complications, and no patients underwent revision surgery. The WPSF group had a significantly shorter operation time than the OPSF group (68.1 ± 9.8 vs 76.1 ± 9.0 minutes, $P = 0.005$). Moreover, the WPSF group showed less cost of surgery than the OPSF group (48142.1 ± 1430.1 vs 59035.4 ± 1152.7 CNY, $P < 0.001$). There were no significant differences between the two groups in terms of the intraoperative bleeding, length of incision, or postoperative hospitalization time ($P > 0.05$). The accuracy of pedicle screw placement was 95.2% (160/168) in the WPSF group and 96.8% (151/156) in the OPSF group, with no significant difference between the groups ($P = 0.432$).

Conclusion: Both WPSF and OPSF were safe and effective for the treatment of thoracolumbar fracture. Although the two groups showed favorable clinical and radiologic outcomes through to final follow-up, we recommended the minimally invasive WPSF given its shorter operation time and lower cost of surgery.

Key words: Spinal fractures; Minimally invasive; Thoracolumbar; Wiltse approach; O-arm navigation

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Introduction

Traumatic spinal fractures occur frequently in the weakest biomechanical location of the thoracolumbar junction (T₁₀–L₂), which accounts for 90% of all spine fractures^{1,2}. Posterior open surgery is one of the most common surgical methods for the treatment of thoracolumbar fractures³. There are several ineluctable drawbacks in conventional open posterior pedicle screw fixation. The muscles along the spine are stripped from the bone portion of the spine, exposing the facets and transverse processes to position the screws accurately. This could lead to complications associated with the surgical approach, including excessive intraoperative bleeding, intramuscular loss of innervation and ischemia, and even long-term muscle atrophy and scarring, which are related to intractable back muscle pain and dysfunction^{4–6}. Anatomically, the posterior muscles and ligaments of the thoracolumbar spine play an important role in maintaining stability. Therefore, these muscles and ligaments should be well-preserved in operations of thoracolumbar vertebral fractures⁶.

In 1968, Wiltse *et al.*⁷ first proposed a paraspinous muscle approach between the multifidus and longissimus, which retained the integrity of the posterior ligament complex and could produce less bleeding and surgical trauma compared with the traditional open approach. Li *et al.*⁶ found that the Wiltse approach had obvious advantages over the conventional open method in terms of operative time, blood loss, postoperative drainage, postoperative hospitalization time, and postoperative improvement in the VAS score. Liu *et al.*⁸ reported that the multifidus cross-sectional area decreased by only 7.6% in the Wiltse group compared to 35.4% in the posterior open group between pre-op and the last follow-up. This suggests that the Wiltse approach results in a lower incidence of multifidus atrophy and fatty infiltration, making it effective as a minimally invasive approach for thoracolumbar fracture.

In recent years, various fluoroscopic-based navigation systems have been introduced that provide information on the elaborate bony anatomy and have been clinically evaluated^{9–13}. The O-arm system is an intraoperative imaging platform that, combined with the Stealth Station navigation system, can be used to increase the accuracy of pedicle screw placement. Compared to traditional C-arm fluoroscopy, O-arm-based navigation has several advantages, such as high-quality multidimensional image, larger surgical fields, and robotic positioning^{11,12}. Van *et al.*¹³ performed a prospective multicenter clinical registry of thoracic, lumbar, and sacral pedicle screw placement using O-arm navigation to assess the accuracy of screw placement. They evaluated a total of 1922 screws in 353 patients and found that only 2.5% of the screws were misplaced. Silbermann *et al.*¹¹ assessed the accuracy of pedicle screw placement in the lumbar-sacral spine between a free-hand technique and O-arm-based navigation method. The results indicated an accuracy rate of 99% in the O-arm group compared to 94.1% in the free-hand group.

With the tremendous development of minimally invasive techniques, such as the Wiltse approach, percutaneous pedicle screw placement under fluoroscopy, and O-arm-based navigation systems for the implantation of pedicle screws, the incidence of the aforementioned approach-related complications can evidently be reduced. As a result, the patient can experience a smaller incision, rapidly reduced pain, shorter hospitalization stay, and a rapid return to life and work^{3,4,6,8,14–16}. These techniques fully abided by the concept of Enhancing Recovery After Surgery (ERAS) in orthopaedics¹⁷.

Nevertheless, for many minimally invasive techniques, we required a better understanding of the surgical indications to guide the selection of appropriate and better minimally invasive methods. Fan *et al.*⁵ compared the Wiltse approach and percutaneous pedicle screw placement under fluoroscopy for thoracolumbar burst fracture and found that both surgical methods are safe and reliable; ultimately, they preferred the Wiltse approach as a better choice in terms of radiation exposure, cost of surgery, learning curve, and reduction of kyphosis. In this study, we first performed a comparison of the Wiltse approach and percutaneous pedicle screw fixation under O-arm navigation for the treatment of thoracolumbar fracture to: (i) study which minimally invasive technique has better clinical efficacy; (ii) evaluate the two minimally invasive techniques for the recovery and maintenance of vertebral compression height; (iii) summarize and compare which minimally invasive technique has more advantages.

Materials and Methods

Inclusion and Exclusion Criteria

Patients with traumatic single-segment thoracolumbar fractures (T₁₀–L₂) treated in our hospital between October 2014 and October 2018 were eligible for enrollment in this study. The study is a retrospective clinical study and has been approved by the First Affiliated Hospital of Soochow University Ethics Committee. All patients signed the consent form.

The inclusion criteria were as follows: (i) a one-level thoracolumbar fracture (T₁₀–L₂) and a lack of neurological deficits and Grade E American Spinal Injury Association (ASIA) classification; (ii) the application of the Wiltse approach (Group A) or O-arm navigation (Group B) as the minimally invasive technique for treating injuries lasting less than 1 week; (iii) during the follow-up period of more than 12 months, all patients had complete clinical and imaging data for the final overall results evaluation. The exclusion criteria were as follows: (i) pedicle fracture, multilevel fracture, pathologic fracture, or severe osteoporotic fracture (bone mineral density [BMD] t score < –2.5); (ii) previous surgery at the fracture site; (iii) age <20 or >65 years; (iv) other injuries requiring surgery; and (v) other diseases, such as infection, tumor, metabolic disease, etc.

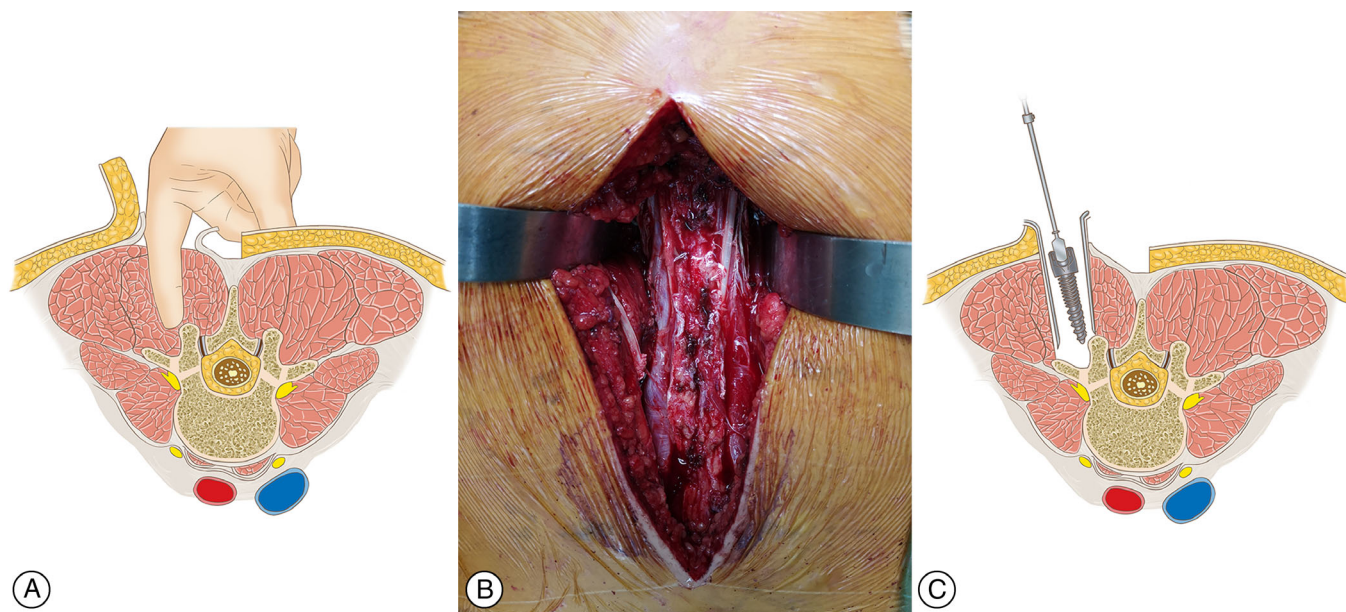


Fig. 1 Mini-open surgery by the Wiltse approach. Cut the lumbodorsal fascia 1.5 cm next to the spinous process and bluntly separate the space between the longissimus and multifidus muscles with the fingers (A). The entry point of the pedicle screws was exposed by the bilateral Wiltse approach during the operation (B). The pedicle screw was installed after appropriate drilling and probing (C).

Minimally Invasive Techniques

Mini-open Surgery by the Wiltse Approach

The patient was placed in a prone position after the administration of general anesthesia. The surgeon made a midline incision of approximately 8 cm at the operative region following routine sterilization and draping. The skin, subcutaneous tissue, and lumbodorsal fascia were cut successively and the gap between the longissimus and multifidus muscles was separated bluntly to expose the entry point of the pedicle screw path (Fig. 1A, B). After the appropriate drilling and probing, six pedicle screws were installed sequentially by hand with the aid of C-Arm (Fig. 1C). After the two connecting rods were installed, the screws were tightened to reposition the anterior column of the vertebral body. The position of the internal fixation and restoration of the fracture centrum were again examined by radiology.

Percutaneous Pedicle Screw Fixation under O-Arm Navigation

Because percutaneous pedicle screw technique requires a long learning curve, the operation was performed by three surgeons with more than 2 years' experience in navigated spinal surgery. After satisfactory general anesthesia, the patient was placed in a prone position on a Jackson radiolucent table, and the surgical site was sterilized and draped. A reference frame was installed on the spinous process following a small incision and removal of the peripheral soft tissue. The O-arm (Medtronic, CO, USA) performed a first scan to acquire an intraoperative 3D image and the radiological data

was transferred to a StealthStation navigation system (Medtronic, CO, USA) (Fig. 2A). The surgeon moved the passive planar probe to confirm the entry point of the stab incision, guided by the 3D image navigation system. After performing a mini-incision, the pedicle screw was tapped and inserted with the aid of the images provided by the navigation equipment while the optimal trajectory was constructed (Fig. 2B). A total of six pedicle screws were placed in the fractured vertebral body and its upper and lower vertebrae (Fig. 2C). The connecting rods were prebent properly and then inserted percutaneously. Then the tailcaps were tightened and the height of the fracture vertebra was restored by distracting the pedicle screws appropriately (Fig. 2D). Finally, the O-arm performed another scan to confirm the correct position of the internal fixation.

Outcome Measures

Visual Analog Scale

We appraised the efficacy of the procedure by using the VAS scores preoperatively, postoperatively, and at the final follow-up. The VAS scoring system had a total of 10 points, with 0 point meaning no pain and 10 points meaning worst imaginable pain.

Oswestry Disability Index

The ODI was used to assess the pain and physiological function preoperatively and at the final follow-up. It included 10 sections and each section has a total score of 5, and was

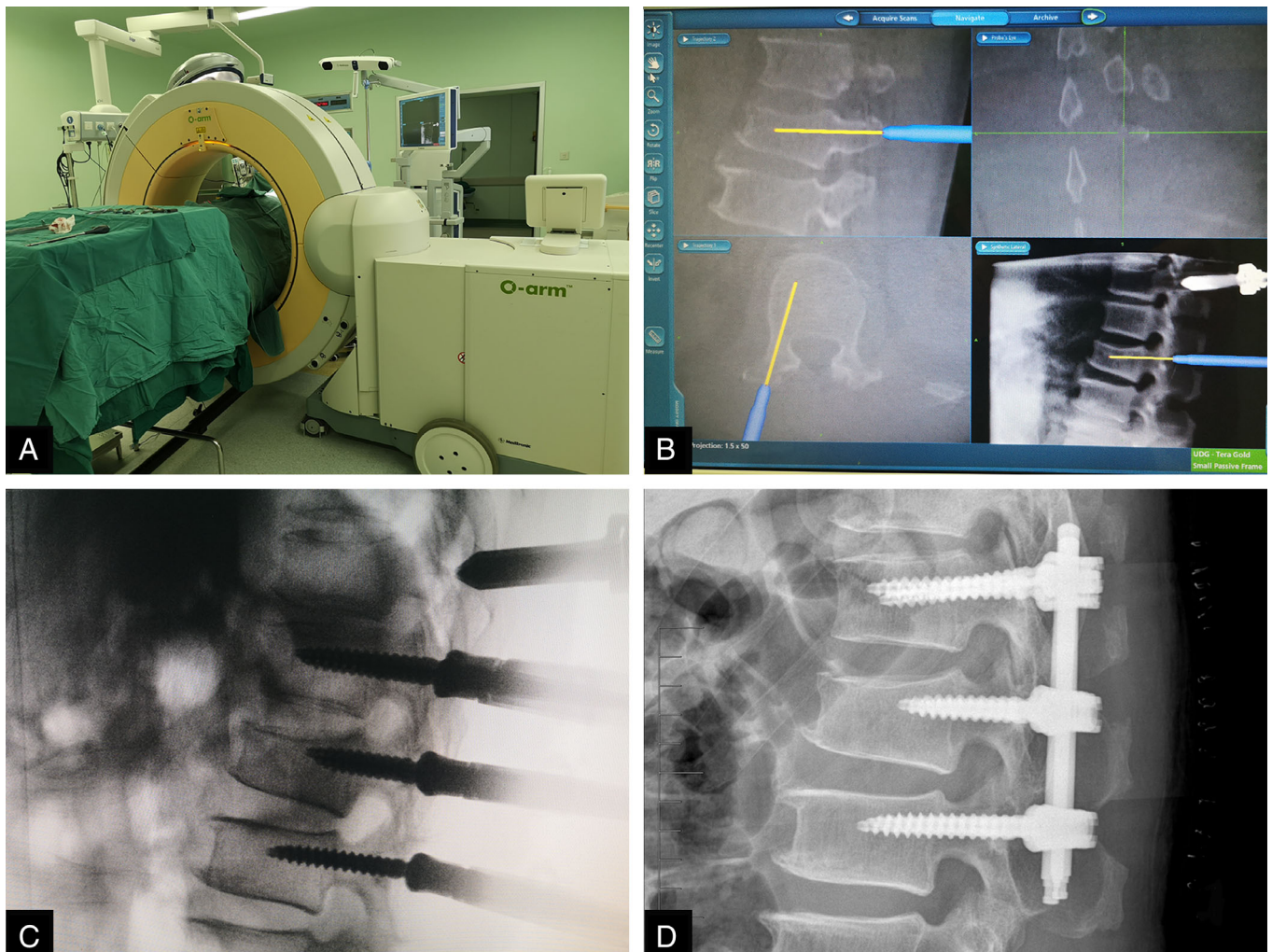


Fig. 2 Percutaneous pedicle screw fixation under O-arm navigation. Setup the O-arm imaging system and StealthStation navigation (A). Move the passive probe to obtain the optimal screw trajectory guided by the 3D image navigation system (B). Six pedicle screws including the affected vertebral body were implanted (C). Restore the height of fractured vertebral body by placement of connecting rod percutaneously and proper distraction of pedicle screws (D).

calculated by the formula: (total scores/[5 × number of sections answered]) × 100%¹⁸.

Imaging Evaluations

Accuracy of Pedicle Screw Placement

The accuracy of pedicle screw placement was assessed using coronal and axial reformatted CT images. The position of the pedicle screw was considered to be misplaced when it was extrapedicular or had broken through the anterior edge, cephalad, and caudal endplates of the vertebral body⁶.

Local Cobb Angle

The LCA reflected the changes in segmental kyphosis, was assessed between the superior endplate of the upper adjacent

vertebra and the inferior endplate of the lower adjacent vertebra.

Vertebral Wedge Angle

The VWA also showed the segmental kyphosis of the fractured vertebra, and was measured between the superior endplate and the inferior endplate of the fractured centrum¹⁹.

Ratio of the Anterior Margin Height of the Fractured Vertebra

The ratio of the anterior margin height of the fractured vertebra (R value) was determined as described by Li *et al.*⁶. It was determined by the ratio of the anterior margin height of

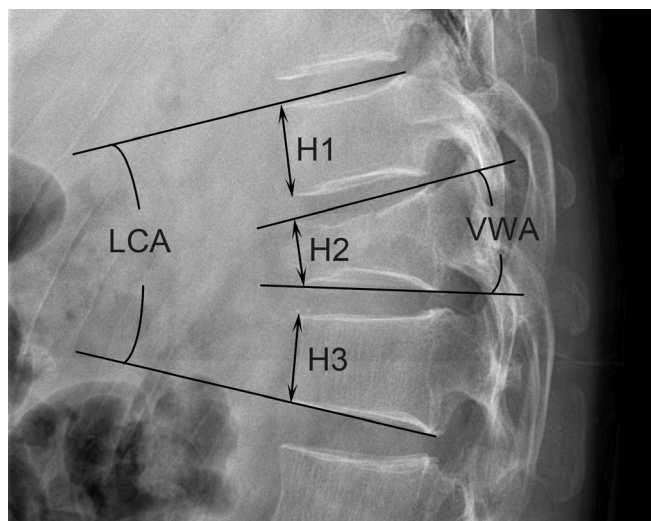


Fig. 3 Measurement and collection of radiologic data on X-ray lateral film. LCA, Local Cobb angle; VWA, vertebral wedge angle; H1, Height of anterior edge of superior adjacent vertebra; H2, Height of anterior margin of fractured vertebra; H3, Height of anterior edge of inferior adjacent vertebra; The ratio of anterior margin height of fractured vertebra (R value) = $(H2 \times 2 / [H1 + H3]) \times 100\%$.

fractured vertebra to the average anterior margin height of upper and lower adjacent vertebral bodies.

The radiographic data were collected by an experienced radiologist who had no knowledge of this study with the software of picture archiving and communication system (PACS, Neusoft, Shenyang, China). The specific details and measuring methods are shown in Fig. 3.

Statistical Analysis

Continuous variables such as age, operation time, blood loss, length of incision, hospital stay, cost of surgery, VAS and ODI scores, LCA, VWA, and R value are presented as mean \pm standard deviation (SD). Categorical variables such as gender, fracture site and type, and the accuracy of pedicle screw are expressed as numbers or percentages. Statistical methods for comparison the two groups included Student's *t* test and χ^2 or Fisher's exact test. A *P*-value of less than 0.05 was regarded as statistically significant. All the data were statistical analyzed using SPSS 19.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

Demographic Data

Fifty-four patients with single-segment, neurologically intact thoracolumbar fractures (T₁₀-L₂) who met the selection criteria were enrolled in this study. The patients were divided into two groups based on the minimally invasive surgery performed. 28 patients who underwent pedicle screw fixation through the Wiltse approach were classified as group A

(WPSF), and 26 patients who underwent percutaneous pedicle screw placement under O-arm-based navigation system served as group B (OPSF). Group A included 22 males and six females, and the mean age was 48.6 ± 9.6 (range, 33 - 63 years). Group B included 15 males and 11 females, and the mean age was 45.7 ± 10.6 (range, 29 - 63 years). The general clinical characteristics of patients and different factors involved in this study were presented in Table 1. The general basic data of patients include age, gender, fracture site and type, blood loss, operation time, total length of incision, cost of surgery, hospital stay, and follow-up duration.

General Results

Subgroup analysis was firstly performed for each variable listed in Table 1 between group A and group B. According to the statistical analysis, there were no significant differences in age, gender, fracture site and type, blood loss, total length of incision, or postoperative hospital stay between the two groups ($P > 0.05$, Table 1). All patients underwent surgery successfully, and no serious complications, such as infection, blood vessel injury, or spinal cord or nerve root injury, occurred. The mean operation time was 68.1 ± 9.8 minutes (48-88 minutes) in group A and 76.1 ± 9.0 minutes (60-95 minutes) in group B, which showed significant difference ($P = 0.005$, Table 1). The cost of surgery for group A was 48142.1 ± 1430.1 CNY, which was significantly lower than that of group B (59035.4 ± 1152.7 CNY, $P < 0.001$, Table 1). All patients experienced a mean follow-up duration of 16.1 ± 2.6 months (12-20 months) in group A (Figs 4 and 5) and 16.0 ± 2.5 months (12-20 months) in group B (Fig. 6), with no significant difference between the groups ($P = 0.840$). During the follow-up period, no patients developed neurological impairment or implant-related complications, and no patients underwent revision surgery.

Outcome Measures

Visual Analog Scale

Subgroup analysis was also performed based on different follow-up time points (Table 2). Regarding the VAS scores, there was no clear discrepancy between the two groups preoperatively, postoperatively, or at last follow-up ($P > 0.05$). However, from the vertical perspective, the VAS scores were reduced pronouncedly from 6.5 ± 1.2 preoperatively to 2.2 ± 0.9 postoperatively, and to 0.4 ± 0.5 at the last follow-up in group A ($P < 0.001$, Table 2). Similarly, in group B, the VAS scores were also reduced from 6.7 ± 1.2 preoperatively to 2.1 ± 0.8 postoperatively and to 0.3 ± 0.5 at the last follow-up ($P < 0.001$, Table 2).

Oswestry Disability Index

For the ODI scores, subgroup analysis showed that there was no significant difference between group A and group B preoperatively and at last follow-up ($P > 0.05$, Table 2). From the vertical perspective, the ODI scores decreased significantly from $92.9\% \pm 4.3\%$ preoperatively to $3.1\% \pm 2.2\%$ at

TABLE 1 Demographic data of patients

	Group A	Group B	P values
Age (years)	48.6 ± 9.6	45.7 ± 10.6	0.314
Gender (male/female)	22/6	15/11	0.099
Fracture site (T10/T11/T12/L1/L2)	1/2/8/10/7	0/1/6/10/9	0.773
Fracture type (A1/A2/A3/B1)	12/1/9/6	14/0/8/4	0.673
Blood loss (mL)	38.8 ± 12.2	36.0 ± 10.7	0.388
Operation time (min)	68.1 ± 9.8	76.1 ± 9.0	0.005
Total length of incision (cm)	7.9 ± 0.2	8.0 ± 0.3	0.087
Hospital stay (days)	4.2 ± 0.9	4.0 ± 0.9	0.565
Cost of surgery (CNY)	48142.1 ± 1430.1	59035.4 ± 1152.7	<0.001
Follow-up (months)	16.1 ± 2.6	16.0 ± 2.5	0.840

CNY, Chinese Yuan.

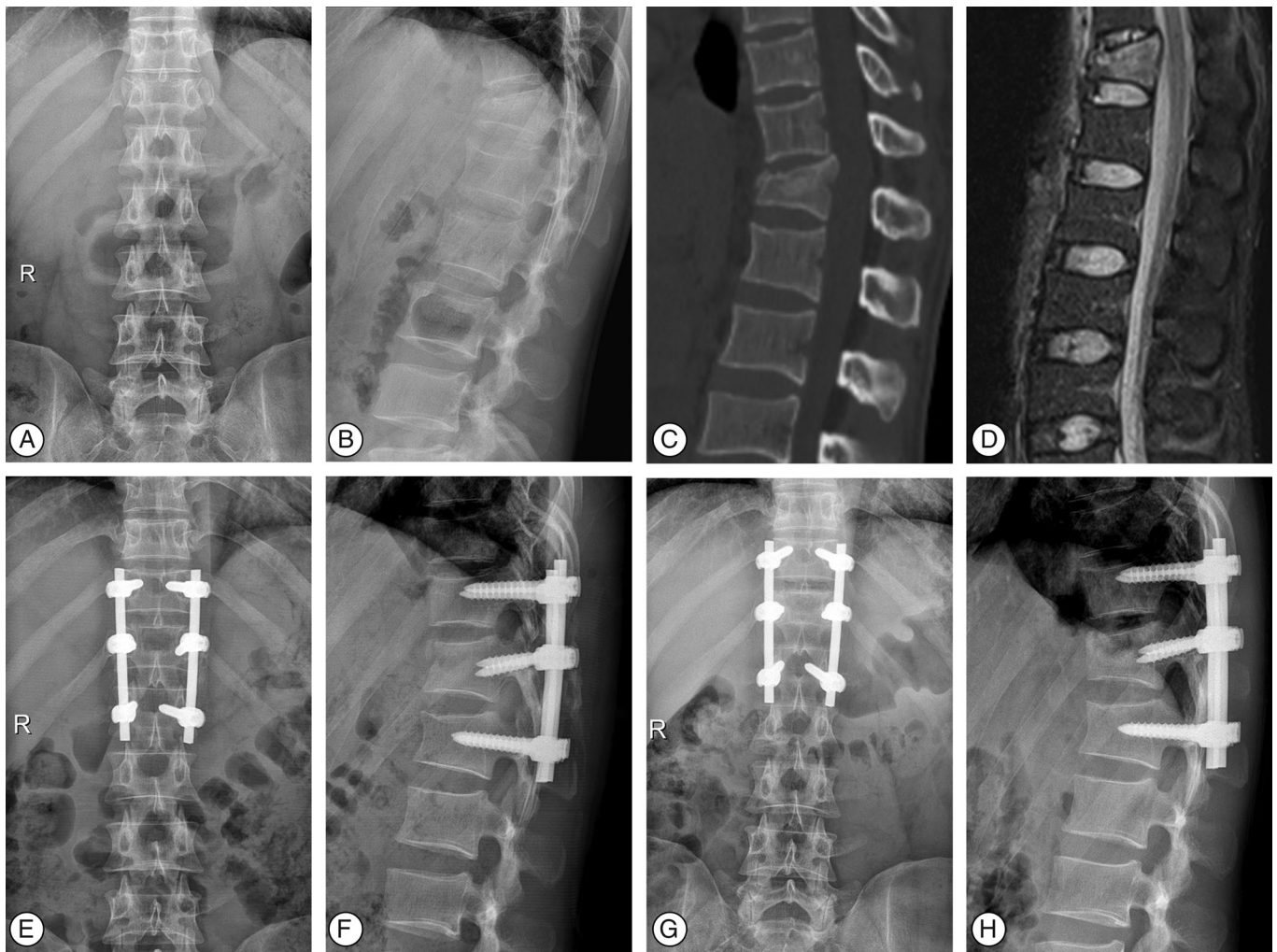


Fig. 4 A 33-year-old male was treated with minimally invasive surgery through Wiltse approach due to compression fracture of T₁₂ (AO type A1) and received a follow-up of 12 months. Preoperative radiographs of anteroposterior and lateral (A, B), reconstructed sagittal CT scan and sagittal plane of STIR sequence in MRI (C, D). Postoperative radiographs of anteroposterior and lateral (E, F). Final follow-up radiographs of anteroposterior and lateral (G, H).

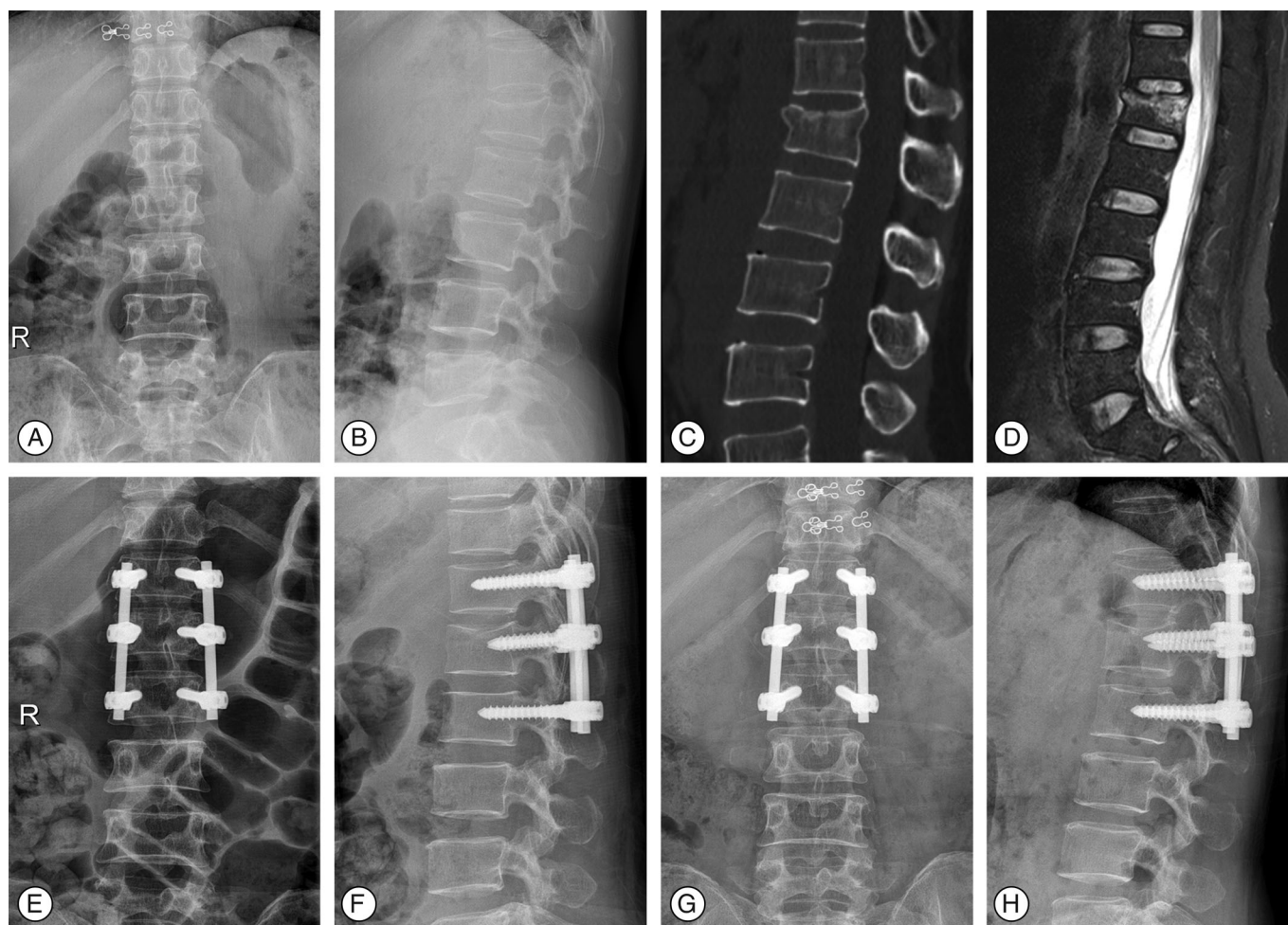


Fig. 5 A 49-year-old female was treated with pedicle screws fixation through Wiltse approach due to compression fracture of L₁ (AO type A1) and completed a follow-up of 18 months. Preoperative X-ray of anteroposterior and lateral (A, B), reconstructed sagittal CT scan and sagittal plane of STIR sequence in MRI (C, D). Postoperative X-ray of anteroposterior and lateral (E, F). Final follow-up radiographs of anteroposterior and lateral (G, H).

the last follow-up in group A, and from $93.3\% \pm 4.4\%$ preoperatively to $2.8\% \pm 2.0\%$ at the last follow-up in group B ($P < 0.001$, Table 2).

Imaging Evaluations

Local Cobb Angle

Similarly, subgroup analysis was performed based on different follow-up time points, correction, and loss (Table 3). The correction value was the preoperative value minus the immediate postoperative value, while the loss value was the final follow-up value minus the immediate postoperative value.

As shown in Table 3, there was no significant difference regarding the LCA between group A and group B at each time point, as well as correction and loss value ($P > 0.05$). However, the LCA in both groups were markedly

decreased after surgery and were well-maintained at the last follow-up ($P < 0.05$, Table 3). The correction and loss value of LCA in group A were $6.9^\circ \pm 6.2^\circ$ and $1.8^\circ \pm 2.9^\circ$, respectively, while those in group B were $6.8^\circ \pm 5.6^\circ$ and $1.5^\circ \pm 2.7^\circ$, respectively, which also showed no apparent differences between the two groups ($P > 0.05$, Table 3).

Vertebral Wedge Angle

Regarding the VWA, subgroup analysis showed that there was no significant difference between the two groups at each time point, as well as correction and loss value ($P > 0.05$, Table 3). From the vertical perspective, the average preoperative VWA was reduced significantly after surgery in both groups, and these values were well-preserved until the final follow-up ($P < 0.05$, Table 3). The correction and loss value of VWA in group A were $8.4^\circ \pm 4.6^\circ$ and $0.7^\circ \pm 1.8^\circ$, respectively, while those in group B were

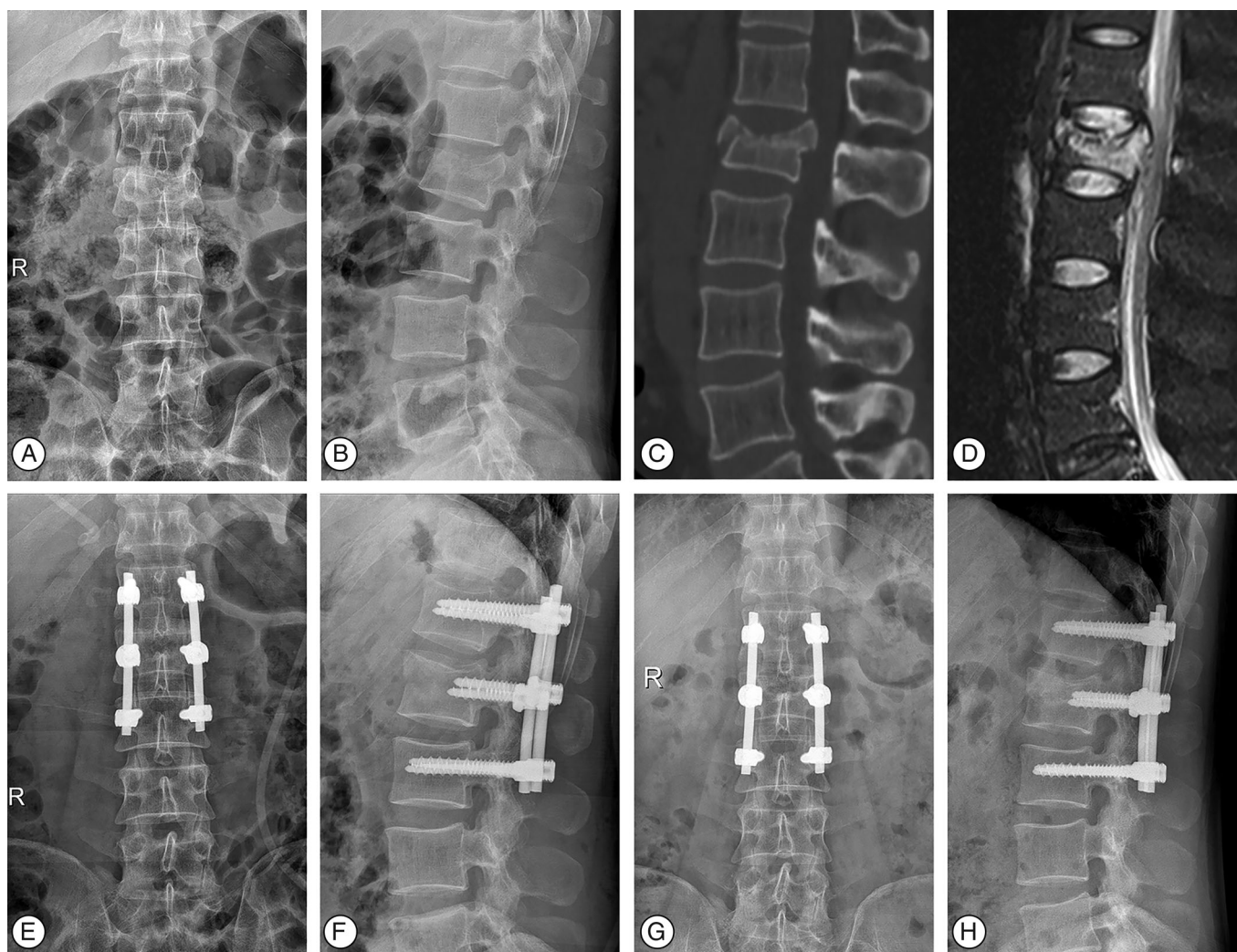


Fig. 6 A 35-year-old male received percutaneous pedicle screws fixation under O-arm navigation due to burst fracture of L₂ (AO type A3) and finished a follow-up of 20 months. Preoperative imaging examinations of anteroposterior and lateral (A, B) radiographs, reconstructed sagittal CT scan, and sagittal plane of STIR sequence in MRI (C, D). Postoperative radiographs of anteroposterior and lateral (E, F). Final follow-up radiographs of anteroposterior and lateral (G, H).

TABLE 2 Clinical data of VAS and ODI score

		Group A	Group B	P values
VAS	pre-op	6.5 ± 1.2	6.7 ± 1.2	0.481
	post-op	2.2 ± 0.9*	2.1 ± 0.8*	0.686
	last	0.4 ± 0.5*	0.3 ± 0.5*	0.729
ODI (%)	pre-op	92.9 ± 4.3	93.3 ± 4.4	0.734
	last	3.1 ± 2.2*	2.8 ± 2.0*	0.605

ODI, Oswestry disability index; VAS, visual analog scale.; * $P < 0.001$ Statistical significance compared to preoperatively.

$8.1^\circ \pm 4.5^\circ$ and $0.2^\circ \pm 2.7^\circ$, respectively, which showed no significant differences between the groups ($P > 0.05$, Table 3).

Ratio of the Anterior Margin Height of the Fractured Vertebra

For the R value, there was also no clear difference between the two groups in the subgroup analysis at each time point, as well as correction and loss value ($P > 0.05$). Postoperatively, the R values had all increased pronouncedly, from 72.4% in group A and from 74.0% in group B to 99.9% ($P < 0.05$, Table 3). At the final follow-up, the R values were 97.4% in group A and 97.2% in group B ($P < 0.05$, Table 3). The correction and loss of the R value showed no significant differences between the groups ($P > 0.05$, Table 3).

Accuracy of Pedicle Screw Placement

The accuracy of pedicle screw placement was 95.2% (160/168) in group A and 96.8% (151/156) in group B, with

TABLE 3 Radiological data of LCA, VWA, R value, and accuracy of pedicle screw placement

		Group A	Group B	P values
LCA (°)	Pre-op	11.2 ± 10.6	10.5 ± 7.2	0.801
	Post-op	4.3 ± 9.4*	3.7 ± 6.2*	0.803
	Last	6.1 ± 10.3*	5.2 ± 7.6*	0.742
	Correction	6.9 ± 6.2	6.8 ± 5.6	0.960
VWA (°)	Loss	1.8 ± 2.9	1.5 ± 2.7	0.714
	Pre-op	12.9 ± 5.8	13.3 ± 5.4	0.773
	Post-op	4.5 ± 4.0*	5.2 ± 3.6*	0.469
	Last	5.1 ± 4.1*	5.5 ± 3.7*	0.769
R value (%)	Correction	8.4 ± 4.6	8.1 ± 4.5	0.805
	Loss	0.7 ± 1.8	0.2 ± 2.7	0.482
	Pre-op	72.4 ± 10.7	74.0 ± 11.0	0.586
	Post-op	99.9 ± 9.1*	99.9 ± 7.5*	0.996
Accuracy (%)	Last	97.4 ± 9.0*	97.2 ± 8.3*	0.931
	Correction	27.5 ± 14.8	25.8 ± 11.7	0.661
	Loss	2.5 ± 5.3	2.7 ± 4.2	0.869
		95.2 (160/168)	96.8 (151/156)	0.432

Correction, Pre-op value minus post-op value; LCA, Local Cobb angle; Loss, Last value minus post-op value; R value, Ratio of anterior margin height of fractured vertebra; VWA, vertebral wedge angle.; * $P < 0.05$ Statistical significance compared to preoperatively.

no significant difference between the two groups ($P = 0.432$, Table 3).

Discussion

In recent years, minimally invasive surgery has developed rapidly, broadening the surgical indications for thoracolumbar fractures without neurological symptoms. The placement of the pedicle screws by minimally invasive techniques does not require the stripping of paravertebral muscles and ligament tissue, thus reducing the incidence of approach-related complications. Multiple studies have demonstrated the advantages of minimally invasive techniques, including reduced pain, less soft tissue injury, shorter hospitalization times, and rapid rehabilitation^{3,4,6,8,14–16}.

Clinical Efficacy

Compared with those of open surgery, minimally invasive treatment with the Wiltse approach or O-arm 3D imaging for thoracolumbar fractures can provide less tissue trauma and bleeding, shorter operation and hospitalization times, and more accurate placement of pedicle screws^{3,6,8,12,13,15}. However, comparisons of the clinical effects and radiological results between the two minimally invasive techniques have not been reported in the literature. In this study, there were no significant differences in intraoperative blood loss, length of incision, or postoperative hospital stay between the two groups. The VAS scores and ODI scores obtained after application of the two minimally invasive techniques were significantly lower than the corresponding preoperative scores, and no difference was found between the groups. Therefore, we believe that the two minimally invasive methods can achieve the same therapeutic effect for thoracolumbar fractures.

Radiologic Outcomes

The accuracy of screw position was 95.2% (160/168) in the WPSF group and 96.8% (151/156) in the OPSF group. There were no complications caused by misplacement during follow-up. The results showed better accuracy in the OPSF group, although no significant difference was found. We reasoned that placement of the pedicle screws through the Wiltse approach provide relatively intuitive vision. In this study, we used short-segment fixation with six pedicle screw combined with intermediate screw fixation in both groups. Most authors reported that short-segment instrumentation with four pedicle screws was not adequate to achieve and maintain the reduction of thoracolumbar fractures and was associated with an unacceptable rate of failure^{20,21}. Compared to conventional four-screw intersegmental fixation, short-segmental fixation combined with intermediate screws enhanced the strength of the fixation, which could be helpful for maintaining the reduction in the height and angle of the fractured vertebra, and allowed much earlier ambulation, which is important for recovery and avoiding complications²². In the current study, the Cobb angle and VWA showed significant differences between pre-op and post-op in both groups. The average postoperative R values of the two groups were all 99.9%, which means that both minimally invasive techniques could basically reset the fractured vertebra to their physiological height. Moreover, no distinct increase was observed in the Cobb angle and VWA between post-op and final follow-up in either group. The correction loss of the R value was only 2.5% in the WPSF group and 2.7% in the OPSF group, with no clear discrepancy between groups. These results indicate that the two minimally invasive techniques have satisfactory effects on the correction of kyphosis and preservation of segment height.

Other Outcomes

Regarding operative time, the Wiltse approach group showed markedly shorter values than the O-arm navigation group, possibly because the placement and operation of the O-arm imaging system is more time-consuming and the surgeon was unfamiliar with the relevant special instruments. In addition, we also compared the cost of surgery of the two groups and found expectedly higher costs in the OPSF group ($59,035.4 \pm 1,152.7$ CNY) compared to the WPSF group ($48,142.1 \pm 1,430.1$ CNY). The principal reason for the cost difference is that more expensive implants and intraoperative neurophysiological monitoring were used in the O-arm navigation group.

Limitations of Study

There are some limitations to the current research. First, the study was retrospective, and the treatment options for the recruited patients mainly depended on their preference, which implied a lack of randomization. However, there were no significant differences in the preoperative clinical and X-ray data between the two groups. Second, only 54 patients were ultimately included in this study; thus, the conclusions drawn from the statistics lack sufficient power. Third, the

follow-up duration in the study was relatively short. An extended observation period should be implemented to better evaluate clinical efficacy, aggravated kyphosis, and the failure of fixation. In the future, randomized controlled trials and additional assessment methods could confirm the results of our study.

Conclusion

The results of our research revealed that two minimally invasive techniques, the Wiltse approach and percutaneous screw placement under O-arm navigation, both had excellent clinical efficacy for thoracolumbar fractures and did not lead to the emergence of troublesome complications. With treatment from the minimally invasive methods, patients in both groups achieved satisfactory outcomes, and kyphosis angle and anterior vertebral column were rectified and maintained until the last follow-up. Nevertheless, the WPSF also provided shorter operation time and lower cost of surgery compared to the OPSF. In the current study, we concluded that WPSF could be the better choice for thoracolumbar fractures.

References

- Cahueque M, Cobar A, Zuniga C, Caldera G. Management of burst fractures in the thoracolumbar spine. *J Orthop*, 2016, 13: 278–281.
- Kim BG, Dan JM, Shin DE. Treatment of thoracolumbar fracture. *Asian Spine J*, 2015, 9: 133–146.
- Liu Z, Li Z, Xing D, Gao H, Peng C, Gong M. Two different surgery approaches for treatment of thoracolumbar fracture. *Int J Clin Exp Med*, 2015, 8: 22425–22429.
- Heintel TM, Dannigkeit S, Fenwick A, et al. How safe is minimally invasive pedicle screw placement for treatment of thoracolumbar spine fractures? *Eur Spine J*, 2017, 26: 1515–1524.
- Fan Y, Zhang J, He X, Huang Y, Wu Q, Hao D. A Comparison of the Mini-Open Wiltse Approach with Pedicle Screw Fixation and the Percutaneous Pedicle Screw Fixation for Neurologically Intact Thoracolumbar Fractures. *Med Sci Monit*, 2017, 23: 5515–5521.
- Li H, Yang L, Xie H, Yu L, Wei H, Cao X. Surgical outcomes of mini-open Wiltse approach and conventional open approach in patients with single-segment thoracolumbar fractures without neurologic injury. *J Biomed Res*, 2015, 29: 76–82.
- Wiltse LL, Bateman JG, Hutchinson RH, Nelson WE. The paraspinal sacrospondylitis-splitting approach to the lumbar spine. *J Bone Joint Surg Am*, 1968, 50: 919–926.
- Junhui L, Zhengbao P, Wenbin X, et al. Comparison of pedicle fixation by the Wiltse approach and the conventional posterior open approach for thoracolumbar fractures, using MRI, histological and electrophysiological analyses of the multifidus muscle. *Eur Spine J*, 2017, 26: 1506–1514.
- Gelalis ID, Paschos NK, Pakos EE, et al. Accuracy of pedicle screw placement: a systematic review of prospective in vivo studies comparing free hand, fluoroscopy guidance and navigation techniques. *Eur Spine J*, 2012, 21: 247–255.
- Scarone P, Vincenzo G, Distefano D, et al. Use of the Airo mobile intraoperative CT system versus the O-arm for transpedicular screw fixation in the thoracic and lumbar spine: a retrospective cohort study of 263 patients. *J Neurosurg Spine*, 2018, 29: 397–406.
- Silbermann J, Riese F, Allam Y, Reichert T, Koepfert H, Gutberlet M. Computer tomography assessment of pedicle screw placement in lumbar and sacral spine: comparison between free-hand and O-arm based navigation techniques. *Eur Spine J*, 2011, 20: 875–881.
- Shin MH, Hur JW, Ryu KS, Park CK. Prospective Comparison Study Between the Fluoroscopy-guided and Navigation Coupled With O-arm-guided Pedicle Screw Placement in the Thoracic and Lumbosacral Spines. *J Spinal Disord Tech*, 2015, 28: E347–E351.
- Van de Kelft E, Costa F, Van der Planken D, Schils F. A prospective multicenter registry on the accuracy of pedicle screw placement in the thoracic, lumbar, and sacral levels with the use of the O-arm imaging system and StealthStation Navigation. *Spine (Phila Pa 1976)*, 2012, 37: E1580–E1587.
- Chang W, Zhang D, Liu W, Lian X, Jiao Z, Chen W. Posterior paraspinal muscle versus post-middle approach for the treatment of thoracolumbar burst fractures: A randomized controlled trial. *Medicine (Baltimore)*, 2018, 97: e11193.
- Tajsic T, Patel K, Farmer R, Mannion RJ, Trivedi RA. Spinal navigation for minimally invasive thoracic and lumbosacral spine fixation: implications for radiation exposure, operative time, and accuracy of pedicle screw placement. *Eur Spine J*, 2018, 27: 1918–1924.
- Sun XY, Zhang XN, Hai Y. Percutaneous versus traditional and paraspinal posterior open approaches for treatment of thoracolumbar fractures without neurologic deficit: a meta-analysis. *Eur Spine J*, 2017, 26: 1418–1431.
- Wang MY, Chang PY, Grossman J. Development of an Enhanced Recovery After Surgery (ERAS) approach for lumbar spinal fusion. *J Neurosurg Spine*, 2017, 26: 411–418.
- Fairbank JC, Pynsent PB. The Oswestry Disability Index. *Spine (Phila Pa 1976)*, 2000, 25: 2940–2952 discussion 2952.
- Lee JK, Jang JW, Kim TW, Kim TS, Kim SH, Moon SJ. Percutaneous short-segment pedicle screw placement without fusion in the treatment of thoracolumbar burst fractures: is it effective?: comparative study with open short-segment pedicle screw fixation with posterolateral fusion. *Acta Neurochir*, 2013, 155: 2305–2312 discussion 2312.
- Güven O, Kocaoğlu B, Bezer M, Aydın N, Nalbantoglu U. The use of screw at the fracture level in the treatment of thoracolumbar burst fractures. *J Spinal Disord Tech*, 2009, 22: 417–421.
- Lakshmanan P, Jones A, Mehta J, Ahuja S, Davies PR, Howes JP. Recurrence of kyphosis and its functional implications after surgical stabilization of dorsolumbar unstable burst fractures. *Spine J*, 2009, 9: 1003–1009.
- Tian JW, Wang L, Xia T, Liu CY, Zhao QH, Dong SH. Posterior short-segmental fixation combined with intermediate screws vs conventional intersegmental fixation for monosegmental thoracolumbar fractures. *Orthopedics*, 2011, 34: e389–e396.