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Study on the Effect of Percutaneous Pedicle Screw Minimally Invasive Surgery in the Treatment of Spinal Fractures and Its Impact on Spinal Function

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Abstract: *Objective:* To observe and study the actual effects of percutaneous pedicle screw minimally invasive surgery in the treatment of spinal fractures and its impact on spinal function. *Methods:* This study included 48 patients with spinal fractures admitted between May 2023 and May 2024. The patients were divided into a control group and an experimental group based on treatment differences, with 24 patients in each group. The control group underwent open internal fixation surgery, while the experimental group received percutaneous pedicle screw minimally invasive surgery. Clinical index improvements, cervical dysfunction index, Japanese Orthopaedic Association scores, and pain level improvements were compared between the two groups. *Results:* The intraoperative blood loss, incision length, operation time, and hospitalization duration in the experimental group were (88.63 ± 18.85), (6.32 ± 1.05), (73.42 ± 4.05), and (12.58 ± 2.56), respectively, compared to (279.95 ± 17.32), (12.89 ± 1.36), (89.93 ± 4.79), and (22.41 ± 2.87) in the control group. Significant differences were observed between the groups, with the experimental group showing superior improvements across all metrics ($P < 0.05$). *Conclusion:* Percutaneous pedicle screw minimally invasive surgery shows more significant effects in treating spinal fractures, particularly in improving cervical and lumbar spine function, enhancing treatment efficacy and safety, reducing pain levels, and shortening recovery time. Clinical application and promotion are recommended.

Keywords: Percutaneous pedicle screw minimally invasive surgery; Spinal fractures; Spinal function

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1. Introduction

Spinal fractures are often caused by external forces, with thoracolumbar fractures being more prevalent. Patients may experience severe pain and deformities, potentially accompanied by spinal cord injury. The spine plays a

crucial role in protecting internal organs, maintaining balance, and supporting body weight, serving as a key structural pillar of the body [1,2]. Severe spinal injuries can lead to paraplegia. Clinical treatments include surgical and conservative approaches, involving fixation, traction, and reduction procedures. The primary goal is to restore spinal mobility, reduce kyphotic deformity, and maintain spinal height and curvature.

With advancements in medical technology, the advantages of minimally invasive techniques have become increasingly evident. Percutaneous pedicle screw minimally invasive surgery requires smaller incisions, results in less intraoperative bleeding, and allows for shorter recovery times. It involves puncturing through the pedicle to fix the fractured vertebra and promote gradual restoration of vertebral height [3,4]. This approach significantly enhances the strength of the affected vertebrae, prevents collapse, and alleviates pain.

This study compares open internal fixation surgery (control group) and percutaneous pedicle screw minimally invasive surgery (experimental group), analyzing improvements in clinical indicators, cervical dysfunction index, JOA scores, and pain levels.

2. Materials and methods

2.1. General information

This study included 48 patients with spinal fractures admitted between May 2023 and May 2024. Based on differences in treatment plans, patients were divided into a control group and an experimental group, with 24 patients in each group. In the control group, there were 15 males and 9 females, aged 26–64 years, with an average age of (43.28 ± 3.89) years. In the experimental group, there were 16 males and 8 females, aged 27–64 years, with an average age of (43.19 ± 3.24) years. Baseline data between the two groups showed no significant differences, making them comparable ($P > 0.05$).

Inclusion criteria: Patients diagnosed with spinal fractures; clear consciousness without osteoporosis; complete medical records; high cooperation from patients and their families.

Exclusion criteria: Patients with old fractures; allergy to anesthetics; not meeting surgical indications; patients with neurological dysfunction or unclear consciousness; coagulation system disorders; comorbid organ diseases; uncooperative patients or those who withdrew midway from the study.

2.2. Methods

The control group underwent open internal fixation surgery: Patients were placed in the prone position, intubated, and monitored for vital sign changes. Soft pads were placed under the chest and hips, and the injured site was determined using X-rays. The surgical incision was made in the midline posterior to the spine, centered on the damaged vertebra. Subcutaneous tissues were incised and separated to expose the spinal injury. Pedicle screws were inserted bilaterally at the injury site, and fixation was completed using connecting rods. Drainage tubes were placed as needed.

The experimental group underwent percutaneous pedicle screw minimally invasive surgery: Patients were placed in the prone position, intubated, and under general anesthesia with vital sign monitoring. Soft pads were placed under the chest and hips, and the injured spine was marked for incision. The lesion was punctured at the damaged vertebra using C-arm fluoroscopy guidance. A guidewire was inserted to reach the anterior third of the vertebra, and pedicle screws were inserted into the pedicle channels. Screws and rods were placed and secured using the C-arm for guidance. The incision was sutured after confirming fixation and reduction.

2.3. Observation indicators

(1) Comparison of clinical improvement indicators: Intraoperative blood loss, incision length, operation time, and hospitalization duration [5].

(2) Comparison of cervical dysfunction index, JOA scores, and pain improvement: The Neck Disability Index (NDI) was used to evaluate cervical dysfunction, covering aspects like pain intensity, concentration, sleep quality, lifting, and recreational activities. Scores range from 0–50, with higher scores indicating worse improvement [6]. The Japanese Orthopaedic Association (JOA) score was used to assess dysfunction in sensation, motor function, and bladder function, with scores ranging from 0–29, where higher scores indicate more severe dysfunction. Pain improvement was evaluated using the Visual Analog Scale (VAS), with scores ranging from 0–10, where lower scores indicate better pain improvement.

2.4. Statistical analysis

Data were processed using SPSS 26.0 software. Measurement data were expressed as mean ± standard deviation (SD) and analyzed using *t*-tests. Categorical data were expressed as [*n* (%)] and analyzed using the χ^2 test. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Comparison of clinical improvement indicators between the two groups

In the experimental group, intraoperative blood loss, incision length, operation time, and hospitalization duration were (88.63 ± 18.85) mL, (6.32 ± 1.05) cm, (73.42 ± 4.05) minutes, and (12.58 ± 2.56) days, respectively. In the control group, these values were (279.95 ± 17.32) mL, (12.89 ± 1.36) cm, (89.93 ± 4.79) minutes, and (22.41 ± 2.87) days, respectively. There were significant differences between the two groups, with the experimental group showing significantly better improvement in all indicators ($P < 0.05$). See **Table 1** for details.

Table 1. Comparison of clinical improvement indicators between the control and experimental groups (mean ± SD)

Group	*n*	Intraoperative blood loss (mL)	Incision length (cm)	Operation time (min)	Hospitalization duration (days)
Experimental	24	88.63 ± 18.85	6.32 ± 1.05	73.42 ± 4.05	12.58 ± 2.56
Control	24	279.95 ± 17.32	12.89 ± 1.36	89.93 ± 4.79	22.41 ± 2.87
t	-	35.614	18.733	12.894	12.522
P	-	0.000	0.000	0.000	0.000

3.2. Comparison of cervical dysfunction index, JOA scores, and pain improvement between the two groups

After treatment, the scores for cervical dysfunction index, JOA scores, and pain improvement in the experimental group were (5.82 ± 1.88), (7.52 ± 4.01), and (1.25 ± 0.86), respectively. In the control group, these scores were (14.77 ± 1.96), (15.64 ± 4.38), and (4.08 ± 0.73), respectively. Significant differences were observed between the two groups, with the experimental group showing superior improvement in all indicators ($P < 0.05$). See **Table 2** for details.

Table 2. Comparison of cervical dysfunction index, JOA scores, and pain scores between the control and experimental groups before and after treatment (mean ± SD)

Group	Cervical dysfunction index		JOA scores		Pain scores	
	Before	After	Before	After	Before	After
Experimental (n = 24)	32.58 ± 2.05	5.82 ± 1.88	23.71 ± 3.08	7.52 ± 4.01	6.02 ± 2.63	1.25 ± 0.86
Control (n = 24)	32.14 ± 2.36	14.77 ± 1.96	23.28 ± 3.26	15.64 ± 4.38	6.38 ± 2.77	4.08 ± 0.73
t	0.690	16.144	0.470	6.699	0.462	12.290
P	0.494	0.000	0.641	0.000	0.647	0.000

4. Discussion

For spinal patients, most experience varying degrees of neurological and organ injuries, which may be caused by external or violent factors. If treatment is not timely, it can lead to spinal deformities, significantly affecting the patient's quality of life [7-9]. Utilizing internal fixation as a treatment method can ensure spinal stability. However, performing open internal fixation surgery on patients can cause traction on the tissues surrounding the fracture. The surgery involves making large incisions and further dissecting the fracture tissues, which directly impacts muscle function. Although this method has more apparent effects and can ensure spinal stability and corrective fixation [10], it results in greater trauma to the patient's body, involves relatively complex procedures, and may lead to scarring, fibrotic edema, nerve root injury, and necrosis. These complications can directly affect postoperative recovery and result in multiple adverse sequelae.

The results of this study show that after treatment, the experimental group had cervical dysfunction index, JOA scores, and pain improvement scores of (5.82 ± 1.88), (7.52 ± 4.01), and (1.25 ± 0.86), respectively, compared to the control group, which had scores of (14.77 ± 1.96), (15.64 ± 4.38), and (4.08 ± 0.73), respectively. There were significant differences between the groups, with the experimental group demonstrating significantly better improvements in all indicators compared to the control group ($P < 0.05$). This indicates that while open internal fixation is a common surgical method that can reposition the vertebrae and increase vertebral height, it causes significant trauma, large wound areas prone to infection, longer postoperative recovery times, and severe pain.

With the continuous development of clinical minimally invasive techniques, the application of minimally invasive surgery in spinal fracture treatment has effectively reduced trauma to the body. Minimally invasive spinal surgery is a relatively common surgical method that involves selecting the pedicle site for puncture, and injecting fillers into the compressed vertebra to restore its height and strength, thereby avoiding vertebral collapse, significantly improving treatment safety, and markedly reducing pain symptoms [11,12]. During pedicle screw fixation, it is ensured that the screws penetrate deeply into the muscle layers. Using fluoroscopic guidance, the percutaneous minimally invasive incision allows precise identification of the fracture site for accurate operation. Assisted by a C-arm machine, damage to surrounding soft tissues is minimized, operation time is significantly shortened, blood loss is reduced, and visibility is enhanced, effectively addressing the drawbacks of open internal fixation surgery. This surgical method not only causes less trauma but also features smaller incisions, protects the patient's lumbar and back functions, ensures the actual stability of the paraspinal muscle and ligament complexes, and effectively avoids multiple postoperative adverse reactions.

5. Conclusion

In summary, in the clinical surgical treatment of spinal fracture patients, percutaneous pedicle screw minimally invasive surgery demonstrates significantly better effects. Its primary benefits include the obvious improvement of cervical and lumbar spine functions, enhanced treatment efficacy and safety, reduced pain levels, and shortened recovery time. Clinical application and promotion of this method are recommended.

Disclosure statement

The authors declare no conflict of interest.

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