

# Comparison of Pedicle Screw Fixation With or Without Cement Augmentation Combined With Single-segment Isthmic Spondylolisthesis in Osteoporotic Spine

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## Research Article

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# Abstract

## Purpose

This study aims to investigate the necessity of cement-augmented pedicle screw fixation in single-segment isthmic spondylolisthesis with osteoporosis.

## Method

Fifty-nine cases were reviewed retrospectively. Thirty-three cases were in the polymethylmethacrylate-augmented pedicle screw (PMMA-PS) group, and the other 26 cases were in the conventional pedicle screw (CPS) group. Evaluation data included operation time, intraoperative blood loss, hospitalization cost, hospitalization days, rates of fusion, screw loosening, bone cement leakage, visual analog scores (VAS), Oswestry disability index (ODI), Lumbar Lordosis (LL), Pelvic Tilt (PT) and Sacral Slope (SS).

## Results

The operation time and blood loss in the CPS group decreased significantly compared to the PMMA-PS group ( $P < 0.05$ ). The average hospitalization cost of the PMMA group was significantly higher than that of the CPS group ( $P < 0.05$ ). There was no significant difference for the average hospital stay between the 2 groups ( $P > 0.05$ ). The initial and the last follow-up postoperative VAS and ODI improved significantly in the two groups ( $P < 0.05$ ). There were no significant differences in VAS and ODI at each time point between the 2 groups ( $P > 0.05$ ). The last postoperative spine-pelvic parameters were significantly improved compared with preoperation ( $P < 0.05$ ). In the PMMA-PS group, the fusion rate was 100%. The fusion rate was 96.15% in the CPS group. No significant difference was found between the two groups for the fusion rate ( $P > 0.05$ ). Nine cases in the PMMA-PS group had bone cement leakage (27.27%). There was not screw loosening in the PMMA-PS group. There were 2 cases of screw loosening in the CPS group. There were no significant differences in screw loosening, postoperative adjacent segment fractures, postoperative infection or postoperative revision between the 2 groups ( $P > 0.05$ ).

## Conclusions

The use of PMMA-PS on a regular basis is not recommended for posterior lumbar interbody fusion for the treatment of single-segment isthmic spondylolisthesis with osteoporosis.

## Introduction

Population aging is an important phenomenon for many countries worldwide. The prevalence of spinal degenerative diseases is increasing in the aging society, and the number of patients undergoing spinal fusion surgery is increasing. Deyo et al.<sup>[1]</sup> reported that the rate of lumbar spine fusion surgery in patients over 60 years in the United States increased 230% between 1988 and 2001. Rajaei et al.<sup>[2]</sup> reported that the rate of spine fusion surgery in patients over 65 years in the United States increased 239.2% between 1988 and 2008. Posterior lumbar pedicle screw fixation is an effective method to solve lumbar

degenerative disease, and it has the advantages of improving spinal stability and fusion rate<sup>[3]</sup>. However, osteoporosis often accompanies the natural aging process of the elderly. Osteoporosis easily results in the loss of trabecular structure and an insecure screw-bone interface connection, which leads to the loosening and removal of screws and failure of internal fixation<sup>[4]</sup>. The loosening rate of conventional pedicle screws is approximately 60% in osteoporotic vertebral bodies<sup>[5, 6]</sup>. How to enhance the stability of the pedicle screw in the osteoporotic vertebral body and reduce the occurrence of internal fixation failures is a problem that the orthopedist must solve.

To improve the screw-holding force, a variety of methods were reported to improve the screw, such as cortical bone divergent trajectory, dual-threaded pedicle screw, expandable pedicle screws, larger diameter pedicle screws, extension pedicle screws, and polymethylmethacrylate-augmented pedicle screws<sup>[5-13]</sup>. Polymethylmethacrylate-augmented pedicle screws are widely used in lumbar surgery. This technique has the advantages of improving the anti-extraction force of screws, and it achieves good functional outcomes and very low revision rates<sup>[14, 15]</sup>.

Isthmic spondylolisthesis is a common spinal disease that requires higher holding power for screws due to its poor spinal stability and the need for pull-up and reduction during the surgery<sup>[16, 17]</sup>. Previous studies reported that polymethylmethacrylate-augmented pedicle screws enhance the holding power of the screw, but few cases reported its use in single-segment isthmic spondylolisthesis in osteoporotic patients. This research further studies this issue and reports the following findings.

## Materials And Methods

Fifty-nine cases with single-segment isthmic spondylolisthesis combined with an osteoporosis spine who received posterior lumbar fusion and were followed up for a minimum of 2 year from January 2014 to December 2017 were reviewed retrospectively. Inclusion criteria: (1) Patients with single-segment isthmic spondylolisthesis who underwent posterior lumbar fusion; (2) Lumbar vertebral bone density measured using dual-energy X-ray absorptiometry, T value < -2.5SD; (3) Three months of conservative treatment did not improve the symptoms, and there were indications for surgery; (4) Patients with I ° or II ° spondylolisthesis; and (5) A complete follow-up information. Exclusion criteria: (1) Lumbar spine bone density test results that suggested normal bone mass or less bone mass; (2) Patients who had undergone lumbar surgery and III ° lumbar spondylolisthesis; and (3) Patients with severe cardiopulmonary and cerebrovascular disease.

Fifty-nine patients were divided into a PMMA-PS group and CPS group according to the presence or absence of bone cement around the screws. Thirty-three cases (7 males and 26 females; 64.67±6.77 years old on average; average bone density -3.35±0.90 SD; 29.91±9.15 m average follow-up time; surgical segment, L4/5 27 cases and L5/S1 6 cases) were in the PMMA-PS group, and the other 26 cases (8 males and 18 females; 60.27±7.38 years old on average; average bone density -3.25±0.59 SD; 29.00±8.32 m average follow-up time; surgical segment, L4/5 11 cases and L5/S1 15 cases) were in the CPS group. There was no significant difference in basic data between the two groups of patients ( $P > 0.05$ , Table 1).

Table 1  
Basic data of two groups of patients

	<b>PMMA -PS group n=33</b>	<b>CPS group n=26</b>
Age(y)	64.67±6.77	60.27±7.38
Gender(male/female)	7/26	8/18
Bone mineral density(SD)	-3.35±0.90	-3.25±0.59
Follow-up time(m)	29.91±9.15	29.00±8.32
Surgical segment		
L4/5	27	11
L5/S1	6	15

### Operative methods and data collection

All patients received open posterior lumbar fusion surgery(TLIF). The use of augmentation is decided by the pre-operative BMD and the mechanical strength of the implanted pedicle screw. Bone cement is usually used when bone density is less than -3.5SD. In the PMMA-PS group, the surgeon made an incision along the posterior midline approach during the posterior lumbar fusion to reveal the pedicle access points in order and strengthened the cement nail channel under the perspective. The hollow pedicle screw was inserted first, and the bone cement was injected through the hollow screw. When the bone cement approached the posterior edge of the vertebral body, the surgeon stopped to inject bone cement. The surgeon injected approximately 0.1 ml of bone cement each time and injected approximately 1.5 ~ 2 ml of bone cement into a single nail channel. In the CPS group, TLIF was performed using a posterior midline open incision approach or a minimally invasive Quadrant duct with bilateral multifidus muscle approach. According to the need for decompression, the surgeon removed the corresponding lamina or facet joint and handled the intervertebral space. Intervertebral bone fusion was performed with autogenous bone or allogeneic bone, and an intervertebral fusion cage was placed in each segment. After the surgery, the patients performed routine lower limb functional exercises on the bed, and the drainage tube was removed when the drainage flow was < 50 ml / d. Patients wore a waist circumference to get out of bed after 3 or 4 d postoperatively and insisted on wearing a waist circumference for 1 month after surgery. Routine anti-osteoporosis treatment (oral calcium carbonate D3 tablet, 600 mg twice daily; zoledronic acid injection, 5 mg once annually via intravenous drip; patients with contraindications to zoledronic acid injection were changed to oral alendronate, 70 mg once weekly) was performed after surgery.

VAS and ODI scores of the two groups of patients were performed preoperatively, postoperatively and during the last follow-up to evaluate clinical efficacy. The operation time, intraoperative blood loss, surgical complications, hospitalization cost and hospital stay were recorded in the two groups. Lumbar

spine X-ray and CT at the last follow-up were used to evaluate the existence of loose screws, bone cement leakage and failure of intervertebral fusion, LL, PT and SS.

The following criteria were used to determine whether intervertebral fusion was successful<sup>[18]</sup>. First, there was no relative displacement of the fusion segment on the X-ray film of lumbar hyperextension and flexion, or the intervertebral angle of the fusion segment was less than 3°. Second, there was no X-ray translucent band around the implant. Third, X-ray or CT showed visible bone tissue growth in or around the fusion cage and continuous cancellous bone bridges between the vertebral bodies of the fusion segment. If at least two of the above three indicators were met, the intervertebral fusion was considered successful. The following criteria were used to determine the existence of loose screws<sup>[19]</sup>. First, the screws were displaced. Second, there was an X-ray translucent band greater than 1 mm around the screws. Third, CT showed undeveloped areas around the nail track. The presence of one or more of the above three indicators indicated loose screws.

### **Statistical analysis**

All data are expressed as means ± standard deviation. The data were analyzed using SPSS 23.0 software (IBM, Inc., Armonk, NY, USA). The operation time, intraoperative blood loss, and hospital stay of the two groups of patients were analyzed using t tests of the summary sample. Preoperative, postoperative, and the last follow-up postoperative LL, PT, SS, VAS and ODI were compared using t-tests of paired samples. The chi-square test was used to compare the fusion, screw loosening, postoperative adjacent segment fractures, postoperative infection or postoperative revision between the two groups of patients. P values < 0.05 were considered to be significant.

## **Results**

All of patients underwent posterior lumbar fusion successfully. The amount of bone cement injected in the PMMA-PS group was 1.5-2 ml in a single nail channel. The operation time and intraoperative blood loss in the CPS group were significantly lower than the PMMA-PS group ( $P < 0.05$ , Table 2). The average hospitalization cost of the PMMA group was significantly higher than that of the CPS group ( $P < 0.05$ , Table 2). No significant difference in hospital stay was observed between the PMMA-PS group and CPS group ( $P > 0.05$ , Table 2). The postoperative and the last follow-up postoperative VAS and ODI improved significantly in the two groups ( $P < 0.05$ , Table 4). There were no significant differences in VAS and ODI at each time node between the 2 groups ( $P > 0.05$ , Table 4). The last postoperative spine-pelvic parameters were significantly improved compared with preoperation ( $P < 0.05$ , Table 4).

Table 2  
Surgery-related information for both groups of patients

	PMMA -PS group(n=33)	CPS group(n=26)
Operation time(min)	211.58±47.30	181.62±41.33 <sup>□</sup>
Intraoperative blood loss(ml)	425.76±264.71	291.15±137.06 <sup>□</sup>
Hospitalization cost(yuan)	82439.91±3492.95	66041.35±1470.28 <sup>□</sup>
Hospital stay(d)	16.91±5.11	16.08±5.93 <sup>□</sup>
Note: □□□ Compared with PMMA -PS group, $P \leq 0.05$ ; □ Compared with PMMA -PS group, $P \leq 0.05$		

Table 4  
LL, PT, SS, VAS and ODI of the two groups in the L4/5-L5/S1 surgical segment

	L4/5		L5/S1	
	CPS group	PMMA -PS group	CPS group	PMMA -PS group
LL, degrees				
Pre-operation	43.41±3.49	42.34±4.39	44.08±3.91	40.74±3.40
Last follow up	47.96±3.73	46.57±5.04	50.28±3.68	46.05±4.02
<i>P</i> value	0.008	0.002	0.000	0.033
PT, degrees				
Pre-operation	23.40±2.32	23.29±3.29	24.56±1.89	22.21±2.21
Last follow up	18.06±2.27	18.13±2.32	17.89±1.90	17.17±2.70
<i>P</i> value	0.000	0.000	0.000	0.005
SS, degrees				
Pre-operation	32.16±6.12	33.62±6.37	30.28±6.44	28.84±3.30
Last follow up	38.55±6.73	38.47±7.08	36.23±7.06	40.15±1.92
<i>P</i> value	0.031	0.011	0.023	0.001
VAS				
Pre-operation	6.09±0.30	6.74±1.10	7.27±0.96	7±0.89
Post-operation	1.55±0.69 <sup>□</sup>	1.63±0.63 <sup>□</sup>	1.80±0.56 <sup>□</sup>	2.17±0.41 <sup>□</sup>
Last follow up	0.66±0.50 <sup>□</sup>	0.67±0.48 <sup>□</sup>	0.80±0.41 <sup>□</sup>	1.17±0.41 <sup>□</sup>
ODI				
Pre-operation	49.27±7.11	50.53±7.91	48.59±5.57	51.33±8.64
Post-operation	15.64±5.28 <sup>□</sup>	13.60±3.22 <sup>□</sup>	14.37±4.26 <sup>□</sup>	12.33±2.66 <sup>□</sup>
Last follow up	3.82±0.98 <sup>□</sup>	3.20±1.52 <sup>□</sup>	3.22±1.60 <sup>□</sup>	3.83±1.60 <sup>□</sup>
Note: <sup>□</sup> Compared with pre-operation, <i>P</i> ≤0.05				

The fusion rate in the PMMA-PS group was 100%. The fusion rate was 96.15% in the CPS group. No significant difference was found between the two groups for fusion rate (*P* > 0.05, Table 3). Nine cases of

bone cement leakage (27.27%) were found in the PMMA-PS group, including 3 cases of paravertebral vein leakage, 4 cases of anterior vertebral vein leakage, 1 case of anterior vertebral nail hole leakage, and 1 case of spinal canal leakage, which did not cause related complications. There was 1 case of postoperative adjacent segment fracture, 1 case of postoperative revision and no screw loosening or postoperative infection in the PMMA-PS group. There was 1 case of postoperative revision, 2 cases of screw loosening, 1 case of postoperative infection and no postoperative adjacent segment fracture in the CPS group. There were no significant differences in screw loosening, postoperative adjacent segment fractures, postoperative infection or postoperative revision between the 2 groups ( $P > 0.05$ ).

Table 3  
The fusion status and postoperative complications of the two groups

	PMMA -PS group (n=33)	CPS group (n=26)	$\chi^2$	P value
Fusion(n)	33/33	25/26	1.291	0.256
Screw loosening(n)	0/33	2/26	2.628	0.105
Fracture of adjacent segment	1/33	0/26	0.807	0.371

This study provided two typical cases (Fig. 1, Fig. 2), both of which showed good imaging findings after follow-up.

## Discussion

Conventional pedicle screws are used as internal fixation instruments in spine surgery, and employing three-column fixation provides good segment stabilization and orthopedic support. However, the loosening of screws easily occurs when osteoporotic patients undergo lumbar internal fixation due to the insufficient fixation strength of osteoporotic vertebrae. The literature states that the loosening rate of pedicle screws in osteoporotic vertebrae is approximately 60%, which is approximately 3-5 times higher than that observed in nonosteoporotic patients<sup>[5, 6]</sup>. It is difficult for the osteoporotic vertebrae to provide good pullout strength for pedicle screws due to the loss of bone mass and sparse bone trabeculae. Due to vertebral body forward and rotation, lumbar-pelvic sagittal imbalance and intervertebral instability<sup>[16, 17]</sup>, the pullout strength of pedicle screws must be higher than the pedicle screws during the surgery, especially in isthmic spondylolisthesis. Biomechanical studies confirmed that the pullout strength of the pedicle screw was significantly reduced when bone density was less than  $0.777 \pm 0.330 \text{ g / cm}^2$ <sup>[20]</sup>. Okuyama et al.<sup>[21]</sup> reported that the maximum pullout strength of the pedicle screw decreased by 60 N for every  $10 \text{ mg / cm}^2$  decrease in bone density, and the pedicle screw did not have sufficient stability in the vertebral body when the bone density was less than  $80 - 90 \text{ mg / cm}^2$ . How to improve the pullout strength of pedicle screws in osteoporotic vertebral bodies is a problem that spine surgeons must face.

To prevent the failure of internal fixation of the lumbar spine due to osteoporosis, the following surgical options are primarily available. Some scholars suggested that the pullout strength of cortical bone screws increased 30 - 60% compared to traditional pedicle screws, which provides a feasible alternative method for traditional pedicle screws<sup>[22]</sup>. Wu et al.<sup>[5]</sup> evaluated 157 patients undergoing lumbar fusion surgery, and the screw loosening rate in the expansion screw group (4.1%) was significantly lower than the ordinary screw group (12.9%). Biomechanical studies<sup>[11]</sup> showed that the average pullout strength of double-threaded screws (2726.8 N) was significantly higher than hybrid-threaded screws (1890.2 N) and single-threaded screws (2213.3 N). However, some scholars<sup>[10]</sup> proposed that double-threaded screws and ordinary pedicle screws showed the same axial extraction force and anti-fatigue strength. Studies showed that larger diameter screws increased pullout strength, and the pullout strength increased 35% when the screw diameter was increased 2 mm<sup>[11, 23]</sup>. Polymethylmethacrylate-augmented pedicle screws are one of the most common ways to prevent the failure of internal fixation in osteoporotic lumbar internal fixation surgery. The use of bone cement significantly improved the pullout force and anti-fatigue resistance of screws. Biomechanical studies reported that the pullout strength of the screws increased 119% -213% compared to conventional pedicle screws<sup>[24, 25]</sup>.

The application of polymethylmethacrylate augmented pedicle screws has clear advantages in the surgical treatment of osteoporosis patients, but the postoperative complications cannot be ignored. The most common complication is leakage of bone cement, which may cause nerve damage, pulmonary embolism, anaphylactic shock and death<sup>[26, 27, 28, 29]</sup>. Previous studies reported that the incidence of bone cement leakage in the strengthening of bone cement nail channels was 5.4% -66.7%<sup>[18, 30, 31]</sup>. The present study found 9 cases (27.27%) of bone cement leakage in the PMMA-PS group, including 3 cases of paravertebral vein leakage, 4 cases of anterior vertebral vein leakage, 1 case of anterior vertebral nail hole leakage and 1 case of spinal canal leakage. There is no systematic study of the preventive measures of bone cement leakage in the strengthening of bone cement nail channels. Based on experience and literature review of percutaneous vertebroplasty, the author summarizes the following measures to prevent bone cement leakage. First, the slow injection of 2-3 ml of dough-like bone cement into each anterior middle of the vertebral body under low pressure, which improved the pullout strength of the pedicle screw and prevent bone cement leakage<sup>[32, 33]</sup>. Second, high-viscosity bone cement has a lower risk of leakage, but the pressure of injection is higher, and the operating time is shorter<sup>[34]</sup>. Third, the tip of the screw should be avoided in the middle third of the vertebral body during screw insertion to prevent bone cement leaking into the spinal canal along the central vein of the vertebral body. When the bone cement approaches the posterior edge of the vertebral body or bone cement leaks, bone cement injection should be stopped immediately. An average of 1.5-2 ml of bone cement was injected into each pedicle in the PMMA-PS group, and there was no symptomatic bone cement leakage.

When fusion internal fixation is performed for patients with osteoporotic lumbar spine disease, most of the literature recommends strengthening of the bone cement nail channel to prevent the risk of screw loosening and fracture after surgery. However, the research subjects<sup>[35, 36, 37]</sup> are patients with multiple segments, mixed with a single segment and double segment mostly. Whether single segments must be

strengthened is not clear. Nagahama et al.<sup>[38]</sup> followed up 40 osteoporotic patients with lumbar spondylolisthesis who underwent single-segment PLIF and found that the fusion rate in the bisphosphonate group was as high as 95% 1 year after surgery, and the vitamin D group was only 65%, and 24% of the patients had fracture of adjacent vertebral body in the vitamin D group. Chen et al.<sup>[39]</sup> followed up 79 osteoporotic patients with lumbar spondylolisthesis who underwent single-segment fusion and found that the fusion rates of the zoledronic acid group and the nonzoledronic acid group were greater than 82% on the basis of taking calcium and vitamin D regularly, but the latter group had a high incidence (17%) of fracture in adjacent segments. Fischer et al.<sup>[40]</sup> performed a literature review and recommended that teriparatide increased bone mass and promoted intervertebral fusion. Therefore, single-segment fusion internal fixation also achieved a higher fusion rate for lumbar spondylolisthesis with osteoporosis with the cooperation of regular anti-osteoporosis, and no significant internal fixation failure was observed. The results of the present study showed that the PMMA-PS group (100%) and the CPS group (96.15%) had satisfying fusion rates, and there was no significant difference between the two groups. There was 1 case of postoperative adjacent segment fractures, 1 case of postoperative revision and no screw loosening or postoperative infection in the PMMA-PS group. There was 1 case of postoperative revision, 2 cases of screw loosening, 1 case of postoperative infection and no postoperative adjacent segment fracture in the CPS group. There were no significant differences in postoperative fusion, screw loosening or postoperative adjacent segment fractures between the 2 groups. The situation may be related to the combined use of zoledronic acid on the basis of regular anti-osteoporosis treatment in postoperative patients.

In lumbar internal fixation surgery, postoperative intervertebral fusion is highly important. Intervertebral fusion is prone to screw loosening and breaking, especially in patients with osteoporosis<sup>[4, 5, 6]</sup>. Therefore, when osteoporotic patients with lumbar spondylolisthesis undergo lumbar internal fixation and fusion surgery, it is necessary to pay attention to the relevant factors of intervertebral fusion. Okuda et al.<sup>[41]</sup> retrospectively analyzed 101 patients with lumbar spondylolisthesis through at least 3 years of follow-up and found that the incidence of delayed fusion was significantly higher in patients over 70 years of age than patients under 70 years of age, but age did not affect clinical efficacy. Park et al.<sup>[42]</sup> studied 881 intervertebral spaces in 784 patients who were treated with TLIF and found that the pear-shaped intervertebral space easily caused cage backward movement and affected intervertebral fusion. Abbushi et al.<sup>[43]</sup> analyzed 40 patients with lumbar spondylolisthesis who underwent lumbar fusion surgery and found that bullet-shaped cages, cages in the central vertebral body, insufficient cage height, stress in the posterior column, and endplate damage were risk factors that led to postoperative fusion failure. Kimura et al.<sup>[44]</sup> followed up 1,070 patients who underwent PLIF, including 76 patients with isthmic spondylolisthesis, and suggested that because of the angle and pear shape of the intervertebral space, L5/S1 had a large degree of spatial mobility, which easily caused the cage to move backward. For the effects of the abovementioned factors on intervertebral fusion, based on our experience and literature review, we performed the following measures to avoid risks. First, cages were not placed in the middle of the weak endplate, especially in patients with osteoporosis and pear-shaped intervertebral spaces. Second, damage of the cartilage endplate was avoided during the surgery. Third, the size of the cage was

slightly larger than the size measured during the surgery. When the fusion segment was L5 / S1, an angled cage was selected, which fit the upper and lower endplates such that the cage obtained a larger weight-supporting area, which reduced the loosening rate of the screws and promoted fusion<sup>[45]</sup>.

The data of the present study showed that the operation time and intraoperative blood loss in the CPS group were lower than the PMMA-PS group, but there was no significant difference in the length of hospital stay between the two groups. The higher blood loss in PMMA group may be related to the longer operation time. The last postoperative LL, PT, and SS of all patients were significantly improved compared with before surgery, and the sagittal balance was corrected. The clinical symptoms of the two groups of patients improved significantly compared to before surgery, which is related to nerve decompression, reduction of spondylolisthesis and improvement of spine-pelvic parameters. At the final follow-up, there were no significant differences in VAS or ODI scores between the two groups.

There are several deficiencies in this study. First, this study was a single-center retrospective study, and more prospective studies are needed. Second, the follow-up time was short, and the sample size was small. Only patients with I ° and II ° lumbar spondylolisthesis were included, and cases with III ° lumbar spondylolisthesis were not included, which may bias the conclusions. Third, the sequence of bone cement injection and screw placement was not clear.

## Conclusions

When osteoporotic patients with single-segment isthmic spondylolisthesis undergo lumbar fusion internal fixation, the use of PMMA-PS achieved similar clinical effects as CPS. Ordinary pedicle screws have the advantages of avoiding postoperative bone cement leakage, less operation time, and less intraoperative blood loss. Routine use of PMMA-PS is not recommended in osteoporotic patients with single-segment isthmic spondylolisthesis. Patients with osteoporosis must pay attention to regular anti-osteoporosis treatment after lumbar fusion internal fixation. The treatment of bisphosphonates and teriparatide is necessary. When using PMMA-PS, the amount of bone cement injection should be strictly controlled. When bone cement approaches the posterior edge of the vertebral body or bone cement leaks, bone cement injection should be stopped immediately.

## Abbreviations

PMMA-PS Polymethylmethacrylate-augmented pedicle screw; CPS Conventional pedicle screw; VAS Visual analog scores; ODI Oswestry disability index; TLIF Transforaminal lumbar interbody fusion; PLIF Posterior lumbar interbody fusion.

## Declarations

### Ethics approval and consent to participate

This study has been reviewed by the appropriate ethics committee of The First Affiliated Hospital of Guangzhou University of Chinese Medicine and performed in accordance with the ethical standards laid down in an appropriate version of the 1964 Declaration of Helsinki.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

### **Competing interests**

All authors declare that they have no competing interests.

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### **Authors' contributions**

Y.C.T, J.C.P were responsible for the study concept design, analysis and interpretation of data, drafting of the manuscript, and critical revision of the manuscript for intellectual content. Y.C.T, J.C.P and H.Z.G conducted data analyses and all the authors contributed to the interpretation of data. H.S.H and C.G.Z were responsible for the analysis and interpretation of data. Y.H.M, S.C.Z, Y.R.X and G.Y.M conducted data collection and performed preliminary data preparations. All authors read and approved the final manuscript.

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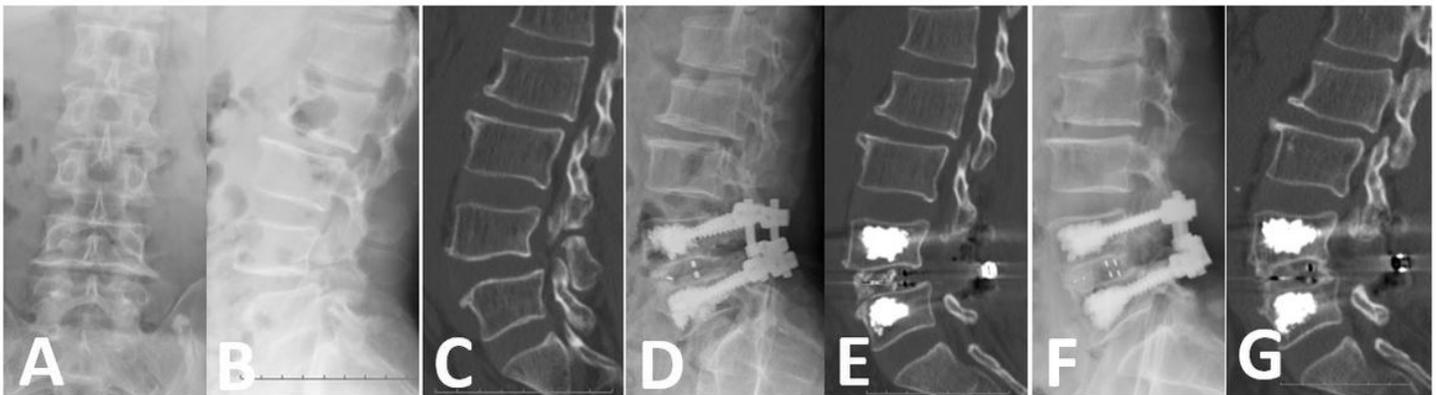
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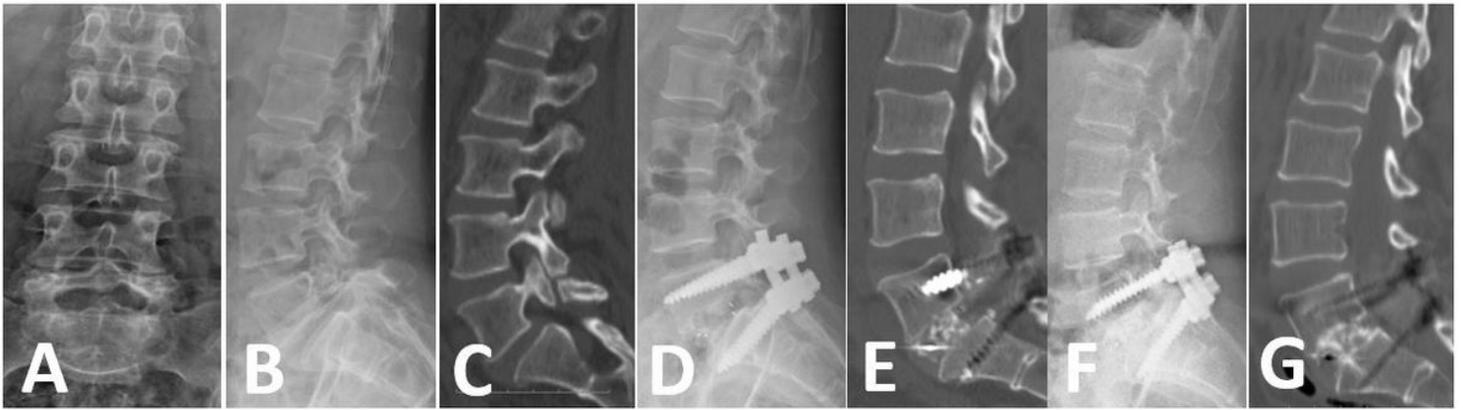
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## Figures



**Figure 1**

Radiological images of a representative case with PMMA-PS. A-G A 62-year-old osteoporotic male with isthmic spondylolisthesis in L4/L5 segments. A-C Preoperative X-rays and CT showed forward-slip of the L4 vertebra and L4 spondylolysis. D-E Postoperative X-ray and CT showed the internal fixation position was good and the bone cement in the vertebrae. F-G Postoperative X-ray and CT at 36 months after fusion surgery showed the internal fixation device did not loosen or break, the vertebra did not show slippage, the intervertebral fusion was good—the bone cement is well filled and there is no obvious cement leakage.



**Figure 2**

Radiological images of a representative case with CPS. A-G A 61-year-old osteoporotic female with isthmic spondylolisthesis in L5/S1 segments. A-C Preoperative X-rays and CT showed forward-slip of the L5 vertebra and L5 spondylolysis. D-E Postoperative X-rays and CT showed the internal fixation position was good and the L5 vertebra was well reset. F-G Postoperative X-ray and CT at 24 months after fusion surgery showed the internal fixation device did not loosen or break, the vertebra did not show slippage, and the intervertebral fusion was good.