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RESEARCH

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Retrospective comparison of cortical bone trajectory and pedicle screw in lumbar fusion for patients over 80, including sagittal balance: a single-center study

Giwuk Jang[1,2], Seungjun Ryu[3,4*], Sanghoon Lee[5], Jeong-yoon Park[1,2], Dong-ah Shin[2,6] and Hoyeol Zhang[2,5*]

Abstract

Background Comparative studies of posterior lumbar interbody fusion with cortical bone trajectory and pedicle screw in older patients, particularly in those aged ≥ 80 years, are rare. This study aimed to retrospectively analyze the clinical and surgical outcomes following posterior lumbar interbody fusion with pedicle screw fixation compared to cortical bone trajectory in patients aged ≥ 80 years with degenerative lumbar spine disease.

Methods We included 68 patients aged ≥ 80 years who underwent degenerative lumbar spinal surgery at our spine center between January 2011 and December 2020. Of these 68 patients, 24 and 44 underwent posterior lumbar interbody fusion with cortical bone trajectory and pedicle screw, respectively.

Results The Visual Analog Scale for back pain was significantly lower in the cortical bone trajectory group than in the pedicle screw group at 6 months postoperatively ($P = 0.049$). The Oswestry Disability Index was significantly lower in the cortical bone trajectory group than in the pedicle screw group at 6 months postoperatively ($P = 0.05$). The estimated blood loss and operation time were significantly lower in the cortical bone trajectory group than in the pedicle screw group ($P = 0.017$ and $P < 0.001$, respectively). Postoperative morbidity was also lower in the cortical bone trajectory group ($P = 0.049$).

Conclusions Despite these limitations, our study findings indicate that cortical bone trajectory is not inferior to posterior lumbar interbody fusion with pedicle screw fixation if there is a need for fusion in older patients aged ≥ 80 years.

Keywords Degenerative lumbar spinal disease, Cortical bone trajectory, Minimally invasive spine surgery, Posterior lumbar interbody fusion with pedicle screw fixation, Octogenarian and over, Cortical bone trajectory

*Correspondence:
Seungjun Ryu
spinesj@eulji.ac.kr
Hoyeol Zhang
hyzhang@nhimc.or.kr
[1] Department of Neurosurgery, Spine and Spinal Cord Institute, Gangnam Severance Spine Hospital, 211, Eonju-Ro, Gangnam-Gu, Seoul 06273, Republic of Korea
[2] Department of Neurosurgery, Yonsei University College of Medicine, 50, Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Republic of Korea
[3] Department of Neurosurgery, School of Medicine, Eulji University Hospital, Eulji University, 95 Dunsanseo-Ro, Seo-Gu, Daejeon 35233, Republic of Korea
[4] IBS Center for Cognition and Sociality, Expo-Ro, Doryong-Dong, Yuseong-Gu, Daejeon 34126, Republic of Korea
[5] Department of Neurosurgery, National Health Insurance Service Ilsan Hospital, 100, Ilsan-Ro, Ilsandong-Gu, Goyang-Si, Gyeonggi-Do 10444, Republic of Korea
[6] Department of Neurosurgery, Severance Hospital, 50-1, Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Republic of Korea

Background

With the development of modern medicine, the human lifespan has dramatically increased. Owing to the resulting aging population, spine surgeons increasingly encounter older patients with degenerative lumbar spine diseases [1–3]. If degenerative lumbar spine disease symptoms do not improve with conservative treatment, spinal surgery should be considered [4].

As the population ages, older adults, especially those over 80, present unique challenges for spine surgeons due to increased comorbidities and diminished bone quality. Chronic pain, which often accompanies degenerative lumbar diseases, refers to pain that persists beyond a typical recovery period (3–6 months) or even after the healing of the initial tissue damage. In such cases, chronic pain becomes a separate condition, requiring active treatment as it no longer serves its original protective function [5]. Timely and appropriate interventions are crucial in preventing the transition to chronic pain in older patients with degenerative lumbar diseases [6].

Recently, minimally invasive spine surgery has become popular due to the development of surgical techniques. Furthermore, endoscopic decompression and fusion are being performed from posterior lumbar interbody fusion with cortical bone trajectory (PLIF c CBT) to minimally invasive surgery-transforaminal lumbar interbody fusion (MIS-TLIF). Therefore, considering the advantages and disadvantages of surgery, performing different surgical procedures according to appropriate indications is essential [7].

Owing to increases in the older adult population and the development of geriatric medicine, the group of older patients is classified as a separate patient group in research and clinical trials [8]. Also, Considering the increasing number of older adults undergoing spine surgery, there is a need for studies that focus specifically on octogenarians, a population with higher risks of postoperative complications due to their age and comorbidities. Comparative studies of PLIF c CBT and conventional fusion techniques in this older patient group are limited. Previous research often grouped patients aged 60–70 together, but we hypothesized that the differences in operative time, blood loss, and postoperative recovery would be more pronounced in patients aged 80 and older.

Therefore, we aimed to retrospectively analyze the clinical and surgical outcomes following posterior lumbar interbody fusion with pedicle screw (PLIF c PS) and PLIF c CBT in older patients aged ≥ 80 years with degenerative lumbar spine disease.

Methods

Patients

The purpose of our study was to analyze the clinical and surgical outcomes following PLIF c PS and PLIF c CBT. At our affiliated hospital, a total of 2583 patients underwent spine surgery for degenerative lumbar diseases from 2011 to 2020. From this cohort, patients aged 80 years or older were selected based on the following inclusion and exclusion criteria.

In cases where osteoporosis assessment was needed, subjective judgment based on MRI or dual-energy X-ray absorptiometry (DEXA) was applied, and patients with severe osteoporosis were excluded from fusion surgery at the surgeon's discretion. Three spine surgeons participated in the study, with one surgeon performing PLIF c CBT and the other two performing PLIF c PS.

Inclusion criteria

Patients aged 80 years or older.

Diagnosis of degenerative lumbar spine disease.

Clinical symptoms, including radiating leg pain with or without low back pain (LBP), neurogenic intermittent claudication.

Failure to respond to conservative treatments (e.g., physical therapy, medications).

Magnetic resonance imaging (MRI) confirming central, lateral, or foraminal stenosis.

Exclusion criteria

Patients with a history of prior spinal surgery.

Patients with spinal infections or requiring reoperation.

Patients with spinal tumors, including nerve tumors.

Patients with severe spondylolisthesis (grade II or greater).

Patients with loss of follow-up or death within 1 year after surgery.

Patients with pathological conditions such as autoimmune disorders, malignancies, post-traumatic deformities, or other syndromic conditions.

Outcome parameters

Preoperative status was assessed using the American Society of Anesthesiologists (ASA) classification [9], and clinical outcomes were evaluated using the Visual Analog Scale (VAS) for LBP and lower extremity pain and the Oswestry Disability Index (ODI) [10]. Sagittal balance was assessed using pelvic tilt, pelvic incidence, sacral slope, and pelvic incidence-lumbar lordosis (PI-LL) mismatch in preoperative spine X-ray. The VAS score was determined using a 0–10 scale, where a score of 0 meant that the patient was asymptomatic, and a score of 10 indicated that the patient exhibited the most severe symptom(s). The VAS and ODI were scored at 6 months and 1 year postoperatively, respectively.

Regarding surgical methods, we compared estimated blood loss (EBL), operation time, and hospitalization period. Postoperative morbidity (neurologic deterioration, cerebrospinal fluid leak, wound infection, pneumonia, cardiac problems, dysuria, epidural hematoma, screw position abnormality, or deep vein thrombosis) was assessed. Sagittal balance parameters were measured preoperatively, at 6 months, and at 1 year to assess spinal alignment. In addition, the occurrence of reoperation and postoperative degenerative changes (relapse, instability, cage subsidence, screw loosening, nonunion, and adjacent segmental degeneration [ASD]) were documented. The union rate was evaluated using the Bridwell grading system, computed tomography, and radiographic findings 1 year postoperatively (Table 1).

Surgical technique

All operations were performed in the prone position. After decompression, discectomy, and posterior lumbar interbody fusion, a traditional pedicle screw was used, followed by transpedicular screw fixation or cortical bone trajectory by cortical screw fixation according to the stenotic levels (Fig. 1).

The CBT is distinguished by a medio-lateral orientation in the transverse plane and a caudo-cephalad orientation in the sagittal plane, which corresponds closely with the delineated trajectory of approximately 25° in the cranial direction and 10° in the lateral direction (Fig. 2A). This trajectory is meticulously engineered to optimize contact with cortical bone, thereby augmenting screw engagement and stability [11]. The PS angle generally ranges from 5 to 10 degrees medially in the lumbar region and a caudo-cephalad angulation is parallel to the endplate (Fig. 2B).

Table 1 The bridwell interbody fusion grading system

Grade	Description
I	Fused with remodeling and trabeculae present
II	Graft intact, not fully remodeled and incorporated, but no lucency present
III	Graft intact, potential lucency present at top and bottom of graft
IV	Fusion absent with collapse/resorption of graft

Statistical methods

All statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). One-way analysis of variance was used depending on the characteristics of the variables being compared, and a post-hoc Bonferroni analysis was performed. Fisher's exact test was used to analyze contingency tables, which showed a tabular representation of categorical data. The Freeman–Halton extension was applied, and the test yield probability value was defined as the probability of the observed array of cell frequencies plus the sum of the probabilities of all other cell-frequency arrays (consistent with the observed marginal totals) that are smaller than the probability of the observed array. Statistical significance was set at P-values < 0.05.

Results

Demographic and preoperative data

The study included 29 men and 39 women with a mean age of 81.6 years. The mean follow-up period was 27.4 (12–114) months. Sixty-eight patients underwent surgery, with 38 undergoing single-level procedures and 30 undergoing two-level procedures.

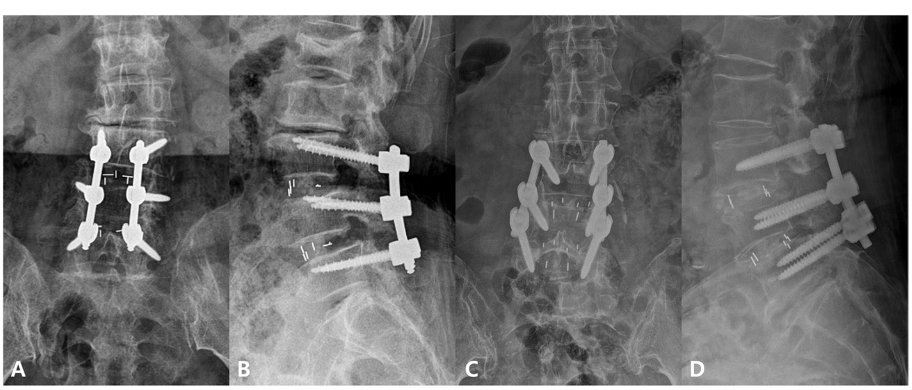

Fig. 1 Anterior–posterior radiograph of the lumbar spine showing each surgical method. **AB** posterior lumbar interbody fusion and cortical bone trajectory (PLIF c CBT), **CD** posterior lumbar interbody fusion with pedicle screw fixation (PLIF c PS)

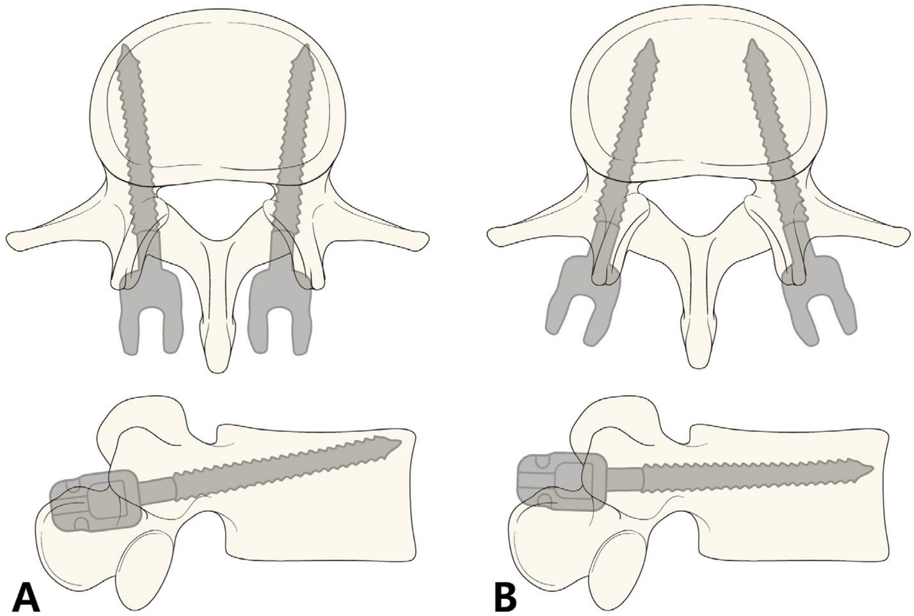

Fig. 2 Schematic diagram for each screw insertion. **A** Axial, sagittal view of the cortical bone trajectory inserted into the vertebral body. **B** Axial, sagittal view of the pedicle screw inserted into the vertebral body

The patients were categorized into two groups according to the surgical method used. Of the 68 patients, 44 (64.7%) and 24 (35.3%) were in the PLIF c CBT and PLIF c PS groups, respectively. No significant between-group differences were found in age, sex ratio, follow-up period, or surgical level (Table 2). There was no significant difference between the ASA classification and the Charlson comorbidity index (CCI) [12]. In addition, preoperative ODI and VAS scores for back pain and leg pain were not significantly different between the two groups.

Table 2 Patients' demographics and preoperative characteristics in the two groups

	PLIF c CBT (*n* = 44)	PLIF c PS (*n* = 24)	*P*-value
Male:Female	17:27	12:12	0.373
Age (years)	81.8 ± 1.9	81.0 ± 1.4	0.070
Height (cm)	155.4 ± 9.5	157.1 ± 9.5	0.493
Weight (kg)	58.8 ± 9.0	59.9 ± 9.6	0.638
BMI (kg/m^2)	24.4 ± 3.4	24.3 ± 3.4	0.926
ASA classification	2.0 ± 0.5	2.0 ± 0.6	0.628
CCI	4.8 ± 1.0	4.8 ± 1.2	0.945
Follow-up duration (month)	25.6 ± 21.1	30.6 ± 32.8	0.507
Interbody fusion levels (mean)	1.41 ± 0.5	1.5 ± 0.5	0.478
Pelvic tilt (%)			0.402
< 20°	15 (34.1)	8 (33.3)	
> 20° but ≤ 30°	16 (36.4)	12 (50.0)	
> 30°	13 (29.5)	4 (16.7)	
PI-LL mismatch (%)			0.550
< 10°	16 (36.4)	7 (29.2)	
> 10° but ≤ 20°	12 (27.3)	5 (20.8)	
> 20°	16 (36.4)	12 (50.0)	

Data are presented as mean ± standard deviation or number (%)

PLIF c CBT Posterior lumbar interbody fusion with cortical bone trajectory, *PLIF c PS* Posterior lumbar interbody fusion with pedicle screw, *BMI* Body mass index, *ASA* American Society of Anesthesiologists, *CCI* Charlson comorbidity index, *PI-LL* Pelvic incidence-lumbar lordosis

Clinical outcome

The VAS scores for LBP and leg pain decreased with follow-up in each group (Table 3). In the PLIF c CBT group, the VAS score for LBP improved from 3.7 to 1.0. In the PLIF c PS group, the VAS score for LBP improved from 3.7 to 0.8. In the PLIF c CBT group, the VAS score for leg pain improved from 5.5 to 1.1. In the PLIF c PS group, the VAS score for leg pain improved from 5.3 to 0.9 (Fig. 3B). The VAS score for LBP at 6 months postoperatively was significantly lower in the PLIF c CBT group than in the PLIF c PS group ($P = 0.049$; Fig. 3A).

The ODI score decreased during follow-up. After 6 months of follow-up, the ODI scores were significantly lower in the PLIF c CBT group than in the PLIF c PS group ($P = 0.05$; Fig. 3C). The Bridwell fusion rate was not significantly different in each group after 1 year of follow-up.

Table 3 Postoperative patient characteristics in the two groups

		PLIF c CBT (*n* = 44)	PLIF c PS (*n* = 24)	*P*-value
VAS for LBP	Pre-op	3.7 ± 3.0	3.7 ± 2.8	0.980
	6-month f/u	1.1 ± 1.5	2.2 ± 2.4	0.049*
	1-year f/u	1.0 ± 1.8	0.8 ± 1.3	0.589
VAS for leg pain	Pre-op	5.5 ± 2.3	5.3 ± 2.2	0.746
	6-month f/u	1.9 ± 2.5	1.7 ± 2.3	0.745
	1-year f/u	1.1 ± 2.2	0.9 ± 1.6	0.702
ODI	Pre-op	52.3 ± 16.5	51.9 ± 16.3	0.916
	6-month f/u	15.2 ± 15.7	25.1 ± 21.1	0.050*
	1-year f/u	14.1 ± 16.1	13.9 ± 15.4	0.952
Bridwell Grade one fusion	1-year f/u	84%	86%	0.188

Data are presented as mean ± standard deviation or percentage

PLIF c CBT Posterior lumbar interbody fusion with cortical bone trajectory, *PLIF c PS* Posterior lumbar interbody fusion with pedicle screw, *VAS* Visual Analog Scale, *ODI* Oswestry disability index, *Pre-op* Preoperative, *f/u* follow-up

* $P < 0.05$

For sagittal balances between the two groups, pelvic tilt, pelvic incidence, sacral slope, and pelvic incidence minus lumbar lordosis were not significantly different (Table 4).

Comparison of surgical methods and complications

EBL and operation time differed significantly between the two groups ($P = 0.017$ and $P < 0.001$, respectively) (Table 5). EBL and operation time increased in the following order: PLIF c PS and PLIF c CBT.

There was a statistically significant difference in postoperative morbidity between the two groups ($P = 0.049$). Postoperative morbidity was observed in one (6.8%) and four (16.7%) patients in the PLIF c CBT and PLIF c PS groups, respectively. An infectious intervertebral disc was observed in one patient in the PLIF c CBT group. In the PLIF c PS group, angina (n = 1), pneumonia (n = 1), postoperative hematoma (n = 1), and cerebral infarction (n = 1) were reported (Table 6).

There were no statistically significant differences in late complications between the two groups. Regarding morbidity, ASD occurred in three patients (6.8%) in the PLIF c CBT group, of which two underwent revision surgery and one (2.3%) experienced screw loosening. In the PLIF c PS group, ASD, screw loosening, and cage subsidence occurred in one (4.2%) patient, two patients, and one patient, respectively (Table 6).

Discussion

This study assessed 68 consecutive cases of fusion surgery for degenerative lumbar spine disease in patients aged over 80 years and demonstrated favorable outcomes in this patient population. MIS aims to limit tissue damage. This is particularly advantageous in older patients

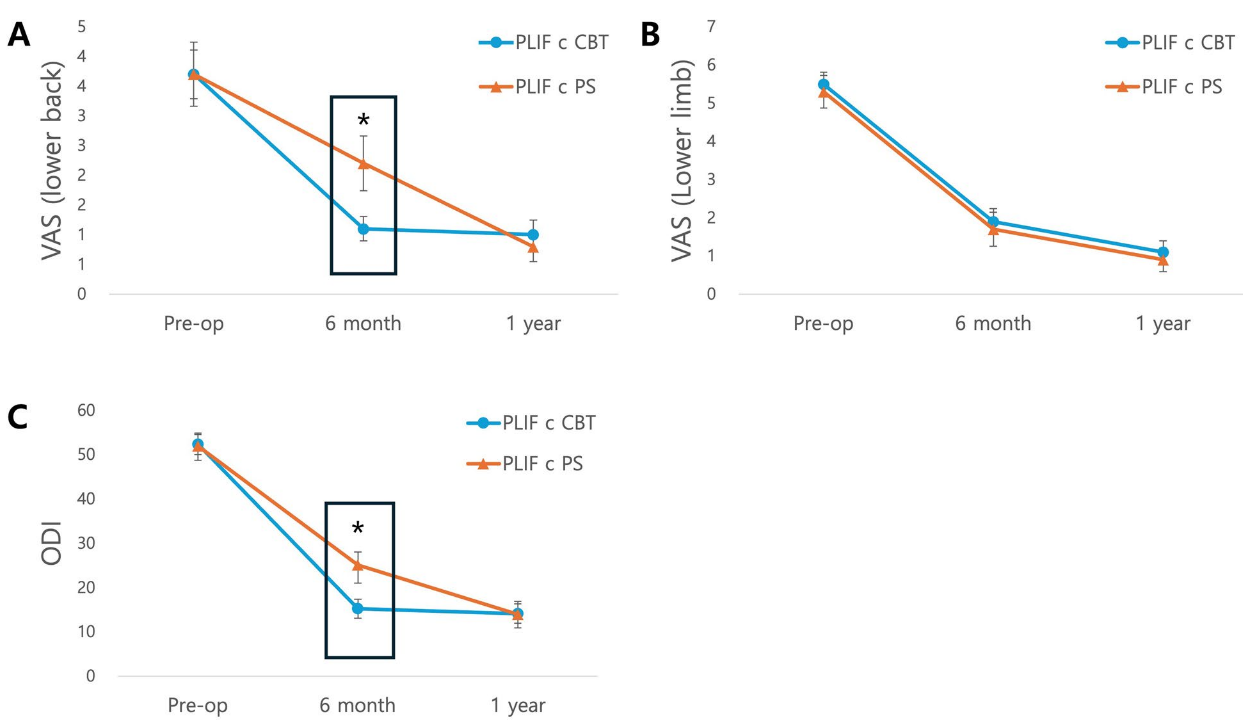

Fig. 3 The statistically significant changes in outcome parameters. **A** The Visual Analog Scale for lower back pain at postoperative 6 month was significantly different between each group (*: $P = 0.049$). **B** The Visual Analog Scale for leg pain did not differ significantly between groups at any time point. **C** Oswestry Disability Index score at postoperative 6 month was significantly different between each group (*: $P = 0.05$)

Table 4 Comparison of patients' sagittal balance between the two groups

		PLIF c CBT (n = 44)	PLIF c PS (n = 24)	P-value
Pelvic tilt (°)	Pre-op	24.4 ± 9.9	23.1 ± 9.3	0.605
	6-month f/u	23.0 ± 8.8	20.2 ± 8.0	0.201
	1-year f/u	23.2 ± 8.5	22.3 ± 9.1	0.659
Pelvic incidence (°)	Pre-op	55.7 ± 13.6	53.9 ± 13.6	0.590
	6-month f/u	54.4 ± 11.8	49.8 ± 22.4	0.274
	1-year f/u	55.3 ± 12.9	53.6 ± 12.2	0.592
Sacral slope (°)	Pre-op	31.3 ± 11.1	30.7 ± 12.0	0.841
	6-month f/u	31.4 ± 10.0	29.6 ± 18.5	0.604
	1-year f/u	32.1 ± 10.3	31.3 ± 13.4	0.797
PI-LL mismatch (°)	Pre-op	16.0 ± 13.0	15.7 ± 11.4	0.923
	6-month f/u	14.0 ± 12.1	11.2 ± 8.3	0.311
	1-year f/u	15.4 ± 12.5	12.8 ± 11.8	0.395

Data are presented as mean ± standard deviation

PLIF c CBT Posterior lumbar interbody fusion with cortical bone trajectory, *PLIF c PS* Posterior lumbar interbody fusion with pedicle screw, *PI-LL* Pelvic incidence-lumbar lordosis, *Pre-op* Pre-operative, *f/u* follow-up

where intraoperative EBL, postoperative mobilization, and wound healing have profound implications [13].

PLIF c CBT is an MIS fusion technique consisting of posterior lumbar interbody arthroplasty and posterior instrumentation using CBT screws [14]. Insertion with a divergent trajectory is advantageous for small cuts and tight screw fixation. First, CBT does not require an incision in the facet joint for insertion [11]. Second, a biomechanical study reported a higher insertion torque of CBT screws compared with conventional pedicle screws [15]. This can be particularly important when performing lumbar fusion in older patients with low bone density. Osteoporosis is a disease characterized by the formation of multiple holes in cancellous bone, leading to a reduction in bone mass and microarchitectural changes that weaken bone strength. In this condition, cancellous bone density decreases first, followed by a reduction in cortical bone density. Because CBT screw fixation is primarily performed near cortical bone structures, it may provide a mechanical advantage in osteoporotic patients, where the cortical bone is initially less compromised. This suggests that CBT could offer relative benefits in such cases compared to PS fixation, which engages more cancellous bone. Future studies are needed to directly compare the efficacy and safety of CBT and PS in osteoporotic patients requiring spinal fusion. In addition, CBT results in less EBL, compared with conventional pedicle screw insertion, and requires only an interarticular incision without an enlarged incision of the mammary gland. Thus, the operation time could be reduced [16].

Increased blood loss during lumbar spinal fusion correlates with increased muscle damage and dissection boundaries [17]. Another theoretical benefit of reducing blood loss is a reduced risk of blood transfusion and other complications in patients with comorbidities more sensitive to low postoperative hemoglobin levels. Since fusion may differ in operation time compared to decompression alone, we suggest that side effects, such as cerebral infarction and pulmonary complications, are more likely to occur. Similarly, the present study demonstrated that lengthy surgery could lead to a greater amount of blood loss, increasing the risk of postoperative complications and delaying functional pain relief. These findings underscore the importance of minimizing operative time in elderly patients to reduce postoperative risks.

Nevertheless, the difference in EBL was significant. This was expected since traditional PS implantation requires extensive exposure of the facet joints. We suggest that the

Table 5 Intraoperative patient characteristics in the two groups

	PLIF c CBT (n = 44)	PLIF c PS (n = 24)	P-value
Estimated blood loss	488.6 ± 570.3	908.5 ± 707.0	0.017*
Operation time (min)	158.9 ± 46.3	253.1 ± 76.0	< 0.001***
Hospital stay (day)	14.8 ± 12.8	16.8 ± 7.8	0.505

Data are presented as mean ± standard deviation or number (%)

PLIF c CBT Posterior lumbar interbody fusion with cortical bone trajectory, *PLIF c PS* Posterior lumbar interbody fusion with pedicle screw

* $P < 0.05$

*** $P < 0.001$

Table 6 Postoperative morbidities and late complications in the two groups

	PLIF c CBT (n = 44)	PLIF c PS (n = 24)	P-value
Postoperative complications	1 (6.8%)	4 (16.7%)	0.049*
Pulmonary complications	0	1 (4.2%)	
Cerebral infarction	0	1 (4.2%)	
Angina	0	1 (4.2%)	
Hematoma	0	1 (4.2%)	
Infection	1 (6.8%)	0	
Late complications	4 (9.1%)	4 (16.7%)	0.439
ASD	3 (6.8%)	1 (4.2%)	
Fusion or instrumentation failure	1 (2.3%)	3 (12.5%)	

Data are presented as mean ± standard deviation or number (%)

PLIF c CBT Posterior lumbar interbody fusion with cortical bone trajectory, *PLIF c PS* Posterior lumbar interbody fusion with pedicle screw, *ASD* Adjacent segmental degeneration

* $P < 0.05$

difference in the screw insertion method of fusion is the reason for the difference between the groups in the ODI and VAS scores of LBP 6 months after fusion.

Complications were divided into postoperative and late complications, and there was a significant difference in postoperative complications between the two groups. According to a study by Kobayashi et al., the risk factors for major complications (cerebral infarction, pulmonary embolism, coronary heart disease, and angina pectoris) after degenerative lumbar spine surgery were preoperative movement disorders, operation time, EBL, and instrument-assisted fusion in patients aged over 90 years [18]. In the present study, postoperative pulmonary complications were found in the PLIF c PS group. These results suggest that minimizing EBL and reducing operative time are key factors in lowering the incidence of complications, particularly in elderly patients with pre-existing comorbidities.

In addition, in the case of PLIF c PS, patients with cerebral infarction and postoperative hematoma required rehabilitation due to motor weakness. Therefore, in older patients requiring fusion, selecting PLIF c CBT, which has advantages in terms of EBL and operation time, would reduce major complications. Previous studies have also found that bleeding amount and operation time were related to complications [19].

Previous studies have demonstrated that there is no difference in the incidence of complications depending on age when decompression or fusion is performed as required [20, 21]. However, very older adults, aged over 80 years, may have biological differences. Oldridge et al. reported an overall mortality rate of 0.5% in 34 418 Medicare patients who underwent lumbar spine surgery. In patients older than 80 years, the mortality rate of spinal fusion was > 10%. They concluded that the 80–85-year-old age group had the highest risk of a significant increase in morbidity and mortality in patients undergoing spinal fusion [22]. Therefore, PLIF c CBT with less bleeding could be advantageous when considering complications. Given the growing number of spinal surgeries in this age group, future studies should focus on optimizing surgical techniques to minimize risk and improve patient outcomes.

Average ASA and CCI values tended to increase with age, which was confirmed to increase the possibility of perioperative complications [23]. However, in the present study, the PLIF c CBT group had relatively few surgical scars, low blood loss, and short operation time, reducing the risk of complications and securing sufficient fixation. No statistically significant differences were found in complications according to ASA and CCI values. This may be due to the limited sample size, and future studies with larger cohorts may reveal more significant trends.

Moreover, as osteoporosis is a common concern in elderly patients undergoing spinal fusion, it would be valuable to further investigate the potential advantages of CBT over PS in this specific patient population. Considering that cortical bone is less affected in the early stages of osteoporosis compared to cancellous bone, CBT may offer superior fixation strength in osteoporotic patients. This hypothesis warrants future prospective studies comparing CBT and PS in patients with osteoporosis, particularly in cases where fusion surgery is unavoidable.

This study had some limitations. First, there are limitations in the retrospective observation and analysis of a 10-year study conducted at a single institution. Second, the indications for surgery in the two study groups were not exactly the same, and patients' preoperative status differed between the two groups. Considering these limitations, we statistically compared the basal conditions of the two groups before the operation and found no significant differences. Third, this study involved three spine surgeons, and differences in their surgical techniques and surgical experience may have influenced the results. Nevertheless, efforts were made to maintain uniformity by performing the surgeries in the same institution and in the same environment as much as possible. Fourth, owing to the small number of cases, comparing the results for each level was difficult; consequently, the average of all surgery levels was compared. Finally, there was a lack of long-term clinical follow-up, as the risk of recurrence is usually assessed over 5 years postoperatively in older patients [24]. Natural death could occur in the case of octogenarians from 80 to 85 years of age. Considering these points, further studies may provide evidence that supports improved patient survival after PLIF c CBT or PLIF c PS. Future research should focus on prospective studies that evaluate long-term outcomes and identify optimal surgical approaches for elderly patients, particularly those at high risk for complications and those with osteoporosis.

Conclusions

Older age did not increase morbidity from spinal fusion or reduce patient satisfaction and activity. Although clinical outcomes were similar between the PLIF c CBT and PLIF c PS groups, the PLIF c CBT group had lower postoperative morbidity and fewer complications. Given its advantages of reduced blood loss and shorter operative time, PLIF c CBT may be preferable for octogenarians with higher complication risks. Our study suggests the potential benefits of PLIF c CBT in elderly patients with osteoporosis or comorbidities, but future studies with larger cohorts are needed to confirm these findings. Through further validation, more refined surgical strategies can be proposed for this specific population.

Abbreviations

PLIF c CBT	Posterior lumbar interbody fusion with cortical bone trajectory
MIS-TLIF	Minimally invasive surgery-transforaminal lumbar interbody fusion
PLIF c PS	Posterior lumbar interbody fusion with pedicle screw
LBP	Low back pain
ASA	American Society of Anesthesiologists
VAS	Visual Analog Scale
ODI	Oswestry Disability Index
EBL	Estimated blood loss
ASD	Adjacent segmental degeneration
CCI	Charlson comorbidity index

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Authors' contributions

All the authors have read and approved the final version of the manuscript. GJ: Conceptualization, Methodology, Validation, Formal analysis, Writing–original draft, and Writing–review & editing; SR: Conceptualization, Methodology, Validation, Visualization, Formal analysis, and Writing–review & editing; HZ: Conceptualization, Data curation, Project administration, and Writing–review & editing; SL: Data curation and Resources; JP: Data curation and Resources; DS: Conceptualization.

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Data availability

Demographic and clinical outcome data is provided within the supplementary files.

Declarations

Ethics approval and consent to participate

The Institutional Review Board of National Health Insurance Service Ilsan Hospital approved this study (2022–01-027), and the requirement of informed consent was waived by the IRB staff Insoon Kim due to the retrospective nature of the study. This study was conducted in compliance with the IRB research guidelines of the National Health Insurance Service Ilsan Hospital.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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