




The Safety and Effectiveness of Multi-Segment Cortical Bone Trajectory Screws in Adult Degenerative Scoliosis with Stenosis Among the Elderly: Minimum 5-year Follow-up Study

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Purpose: To evaluate the long-term efficacy and safety of multi-segment cortical bone trajectory screws for treating mild adult degenerative scoliosis with stenosis among the elderly.

Patients and Methods: From January 2018 to December 2019, a total of 41 patients of mild adult degenerative scoliosis with stenosis underwent posterior lumbar decompression, bone graft fusion, and internal fixation, which were retrospectively divided into pedicle screw (PS) group and cortical bone trajectory (CBT) screw group according to different internal fixation methods. The operation time, intraoperative blood loss, immobilization, and length of hospital stay were compared between the two groups. The visual analog score (VAS) of low back and leg pain, Oswestry disability index (ODI), Cobb angle, lumbar lordosis (LL) angle, apex vertebral translation (AVT), coronal balance distance (CBD) and sagittal vertical axis (SVA) were compared between the two groups preoperatively and 6 months, 1 year, 5 years postoperatively. Perioperative and follow-up complications were observed.

Results: The CBT group was superior to PS group in operation time, intraoperative blood loss, immobilization, length of hospital stay ($P<0.05$). The low back VAS and ODI in CBT group were significantly lower than those in PS group at 6 months, 1 year and 5 years postoperatively ($P<0.05$). The leg VAS in CBT group was lower than PS group at 5 years postoperatively ($P<0.05$). The incidence of screw loosening and adjacent segment disease 5 years postoperatively in CBT group was significantly lower than that in PS group ($P<0.05$).

Conclusion: Multi-segment cortical bone trajectory screws is a safe and effective treatment option for mild adult degenerative scoliosis with stenosis among the elderly. This technique features miniinvasive trauma and quick recovery, which might lead to improved long-term quality of life and a reduction in screw loosening and adjacent segment disease rates.

Keywords: cortical bone trajectory screw, adult degenerative scoliosis, stenosis, elderly

Introduction

Adult degenerative scoliosis (ADS) with stenosis is a challenging disease among the elderly in spinal surgery. Its pathological features include disc degeneration, articular process hyperplasia, and coronal/sagittal imbalance, often leading to intractable low back pain and neurological dysfunction.^{1,2} Posterior Lumbar Interbody Fusion (PLIF) with pedicle screw (PS) fixation has become the conventional procedure for patients who fail conservative treatment; PLIF can directly decompress spinal canal, relieve nerve compression, improve nerve symptoms, and provide good spinal stability with relatively high fusion rate, but PLIF requires extensive dissection of paravertebral muscles, causing greater damage to paravertebral muscles and greater damage to posterior ligament complex structures; transforaminal lumbar

interbody fusion (TLIF) has relatively little damage to the posterior structure and preserves part of the posterior ligament complex, which is beneficial to maintaining the stability of the spinal column after operation, reducing the interference to the nerve tissue in the spinal canal and reducing the risk of nerve injury; however, TLIF has limited operating space for severe intervertebral foraminal stenosis cases, and the decompression effect may be affected to some extent.^{3–8} However, osteoporosis and biomechanical interference with multi-level fixation in elderly patients may lead to complications such as screw loosening and adjacent segment degeneration (ASD), especially at the lumbar fixation level.^{9,10}

In recent years, cortical bone trajectory (CBT) screw technology has provided a new idea for spinal fixation by innovating the angle of screw implantation and enhancing the anchoring force with high-density cortical bone at the pedicle-vertebral junction.¹¹ Basic research have confirmed that CBT screws significantly improve the pullout resistance of bone-screw interface compared with traditional PS screws.^{11–13} The entry point of CBT screws is located in the pars interarticularis, which can minimize the destruction of facet joints and thus reduce the incidence of ASD. Moreover, its medial path can reduce the extent of paravertebral muscle dissection, which aligns with accelerated rehabilitation surgery.¹⁴ Currently, CBT is mostly used in single-level lumbar degenerative diseases. However, there is no systematic report on whether CBT can maintain scoliosis correction and reduce the risk of complications in multi-level fixation of ADS with stenosis.

This study is the first to compare the clinical efficacy of multi-level CBT screws and PS fixation combined with PLIF (L1-5 or L2-5) in ADS with stenosis among the elderly. Through retrospective analysis, the correction of scoliosis parameters, functional scores, postoperative complications, etc, between the two groups of patients were compared, providing a better solution for ADS with stenosis requiring multi-level fixation.

Materials and Methods

General Information

A retrospective analysis of clinical data of 19 patients (CBT group) who received CBT screw treatment from January 2018 to December 2019 due to ADS with stenosis was conducted. Twenty-two patients (PS group) who received PS treatment due to ADS with stenosis at the same period were selected as a control group. Baseline data of Age, sex, course of disease, bone mineral density, body mass index (BMI), Lenke-Silva type II–III, fusion levels, and follow-up time of the PS group matched with the CBT group (Table 1).

Inclusion criteria: 1. The diagnosis of ADS with stenosis is explicit; 2. Age > 65 years; 3. Cobb angle < 20°, vertebral rotation ≤ II degree (Nash-Moe method); 4. Scoliosis in the lumbar segment; 5. Lenke-Silva type II–III; 6. Horizontal L5 in the coronal plane and the lowest instrumented vertebra is L5; 7. Follow-up for at least 5 years.

Exclusion criteria: 1. Patients with previous spinal surgery; 2. Patients with spinal infection and spinal tumor; 3. Patients who only received decompression at the responsible lumbar segment without internal fixation; 4. Patients who could not tolerate general anesthesia surgery due to severe underlying diseases; 5. Patients with incomplete follow-up data.

Table 1 Comparison of Baseline Data Between Two Groups

	PS Group	CBT Group	Statistics	P value
Age (years)	68.91±2.65	70.37±2.29	t=-1.87	0.07
Gender (male/female)	7/15	6/13	x ² =0	0.98
Course of disease (months)	8.43±1.78	9.24±1.27	t=-1.65	0.11
Body mass index (kg/m ²)	22.32±1.55	21.67±1.32	t=1.43	0.16
Bone mineral density (T value)	-2.84±0.30	-2.97±0.29	t=1.42	0.16
Lenke-Silva II	16	11	x ² =0.99	0.31
Lenke-Silva III	6	8		
L1-L5	5	4	-	0.6
L2-L5	17	15		
Follow-up time (years)	5.81±0.54	5.64±0.39	t=1.13	0.27

Surgical Procedures

After general anesthesia, the patients were placed prone on the operating bed, and the posterior median approach was taken to strip bilateral paravertebral muscles while preserving the posterior ligament complex structure. Select appropriate screws according to preoperative measurement and intraoperative results, PS screws are generally 6.0mm/4.5cm, and CBT screws are generally 5.5mm/3.5cm. The decompression range of the two groups included the inferior articular process, part of the lamina, and part of the superior articular process at multiple responsible levels. For the PS group, the superior articular process was exposed to the outer edge of the articular process, and the herringbone ridge was selected as the entry point for bilateral fixation using the traditional PS internal fixation system. In the CBT group, the fusion segment was not exposed completely, only dissected to the outer edge of the isthmus and fixed bilaterally with a CBT screw fixation system under fluoroscopic guidance. The screw insertion point of the CBT screw was more medial and inferior than that of the traditional PS screw, and it was close to the isthmus (Figures 1–5). Local autogenous bone was obtained during decompression and cut for intervertebral fusion. Polyetheretherketone cages were routinely inserted in several decompression segments. After asymmetrical compression and de-rotation on both sides of the scoliosis, the screw-rod system was locked. Finally, the incision was rinsed, a negative pressure drain was placed under the unilateral paravertebral muscle, and the suture was performed layer by layer.

Postoperative Treatment

The patients in both groups received regular dressing changes, an intravenous infusion of cefuroxime sodium for 3 days to prevent incision infection, and regular anti-osteoporosis treatment. When the drainage volume was less than 50mL, and the drainage fluid was light blood, the drainage tube was removed, and the brace was worn for walking. The brace was strictly worn for 3 months. The lumbar spine activity gradually increased after discharge, and regular outpatient reexamination was performed.

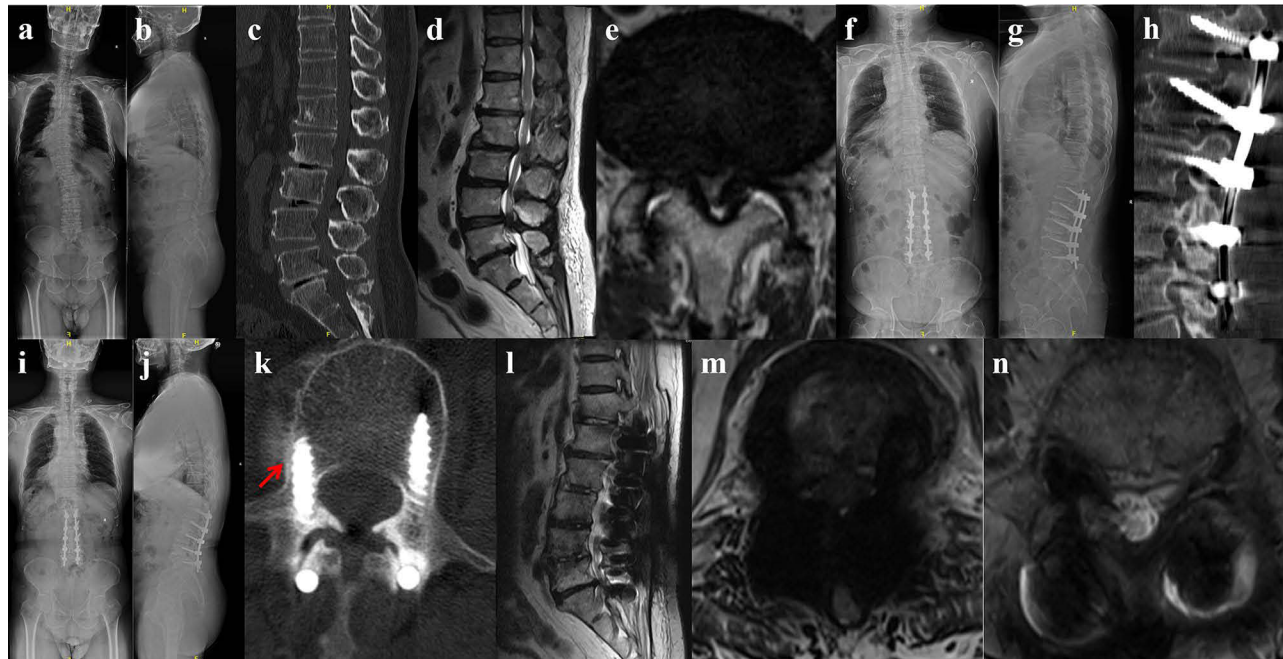


Figure 1 Illustrative case of adult degenerative scoliosis with stenosis (CBT group). Preoperative X-ray: mild scoliosis, lumbar multi-level disc space narrowing (a and b); preoperative CT: Multi-level lumbar disc degeneration (c); preoperative MRI: multi-level lumbar spinal stenosis (L2/3, L3/4, L4/5), bilateral ligamentum flavum hyperplasia and hypertrophy pressing dural sac, bilateral facet joint hyperplasia and cohesion (d and e); X-ray immediately postoperatively: internal fixation system firmly in place (f and g); CT immediately postoperatively: CBT screws in good position (h); X-ray 5 years postoperatively: scoliosis not aggravated (i and j); CT 5 years postoperatively: “corticalization” phenomenon around screws (red arrows), no loosening of screws (k); MRI 5 years postoperatively: adequate spinal canal decompression, no radiographic ASD occur (l–n).

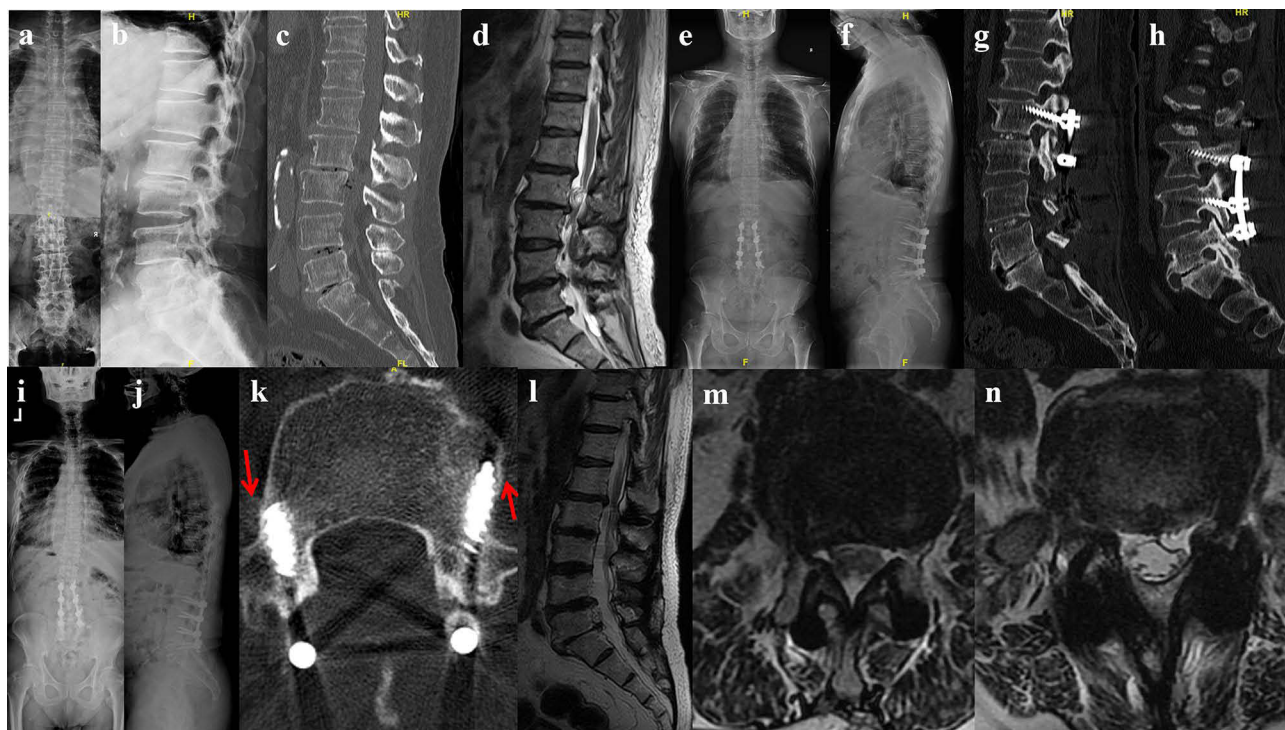


Figure 2 Illustrative case of adult degenerative scoliosis with stenosis (CBT group). Preoperative X-ray: mild scoliosis, lumbar multi-level disc space stenosis, osteophyte hyperplasia (a and b); preoperative CT: Lumbar multi-level intervertebral space height decreased, degeneration is obvious (c); preoperative MRI: multi-level stenosis (L2/3, L3/4, L4/5), cauda equina redundancy, dural sac compression obvious (d); X-ray immediately postoperatively: internal fixation system firmly in place (e and f); CT immediately postoperatively: CBT screws in good position (g and h); X-ray 5 years postoperatively: scoliosis not aggravated (i and j); CT 5 years postoperatively: "corticalization" phenomenon around screws (red arrows), no loosening of screws (k); MRI 5 years postoperatively: no radiographic ASD occur (l-n).

Observation Index

Operation time, intraoperative blood loss, immobilization, and length of hospital stay were observed. The visual analog score (VAS) of low back and leg pain, Oswestry disability index (ODI), Cobb angle, lumbar lordosis (LL) angle, apex vertebral translation (AVT), coronal balance distance (CBD), and sagittal vertical axis (SVA) were observed preoperatively and 6 months, 1 year, and 5 years postoperatively. Perioperative and follow-up complications were observed.

Statistical Analysis

SPSS22.0 statistical software was used for analysis. Qualitative data were described by number of cases and percentage (%). The chi-square test/Fisher exact test was used to compare group differences. Quantitative data conforming to normal distribution were expressed by mean±standard deviation (Mean±SD). Independent sample *t*-test was used for comparison between groups. $P < 0.05$ was regarded as a statistically significant difference.

Results

Comparison of Perioperative Indicators Between Two Groups

Table 2 and Figure 6 show that the CBT group was superior to the PS group in operation time, intraoperative blood loss, immobilization, and length of hospital stay, and the difference was statistically significant ($P < 0.05$).

Comparison of Functional Scores Between Two Groups

Table 3 and Figure 7 show that the low back VAS and ODI in the CBT group were significantly lower than those in the PS group at 6 months, 1 year, and 5 years postoperatively ($P < 0.05$). There was no significant difference in leg VAS between the two groups preoperatively, 6 months, and 1 year postoperatively ($P > 0.05$), but the CBT group was significantly lower than the PS group 5 years postoperatively ($P < 0.05$).

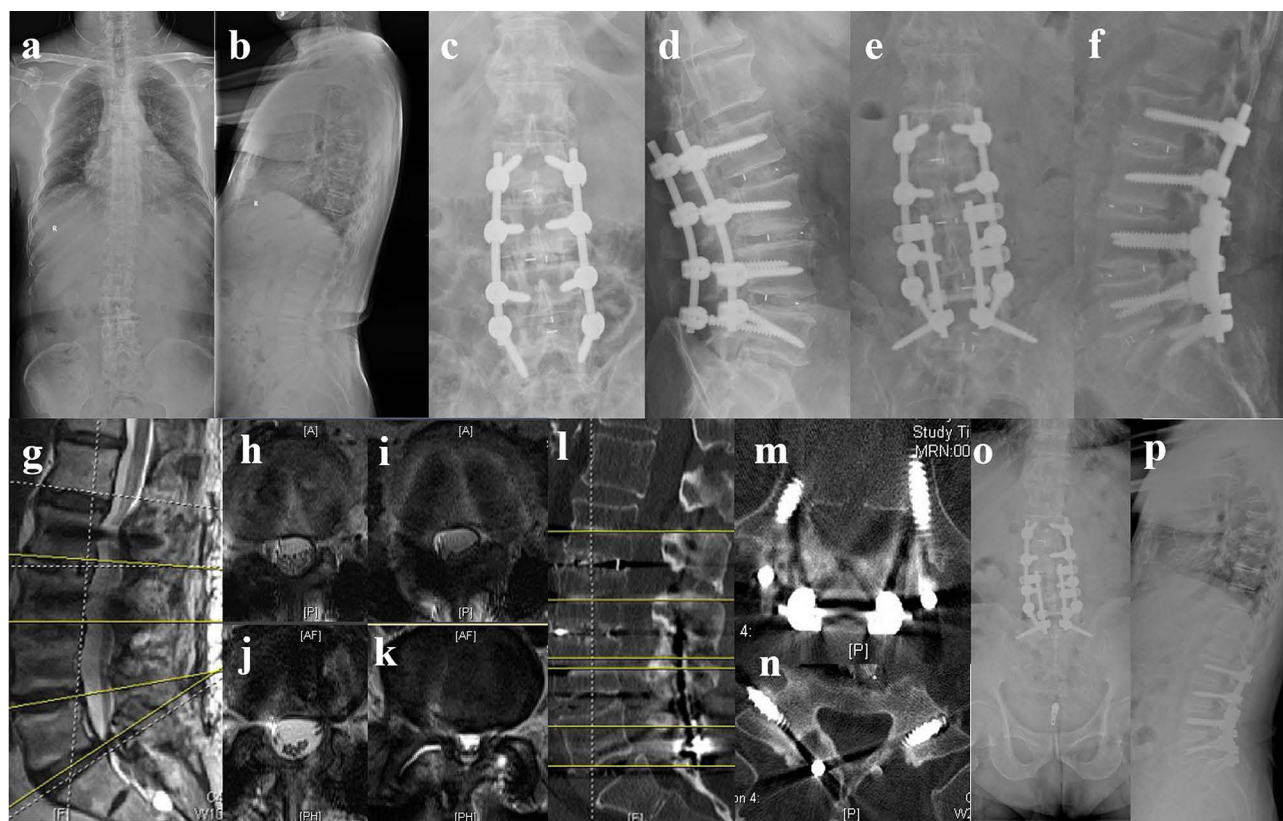


Figure 3 Illustrative case of adult degenerative scoliosis with stenosis (PS group). Preoperative X-ray: mild scoliosis, lumbar multi-level disc space stenosis (a and b); X-ray immediately postoperatively: internal fixation system firmly in place (c and d); X-ray immediately after revision surgery: screws in good position (e and f); MRI 5 years postoperatively: spinal stenosis at L5/S1 (g-k); CT immediately after revision surgery: screws in good position (l-n); X-ray 1 year after revision surgery: scoliosis not aggravated (o and p).

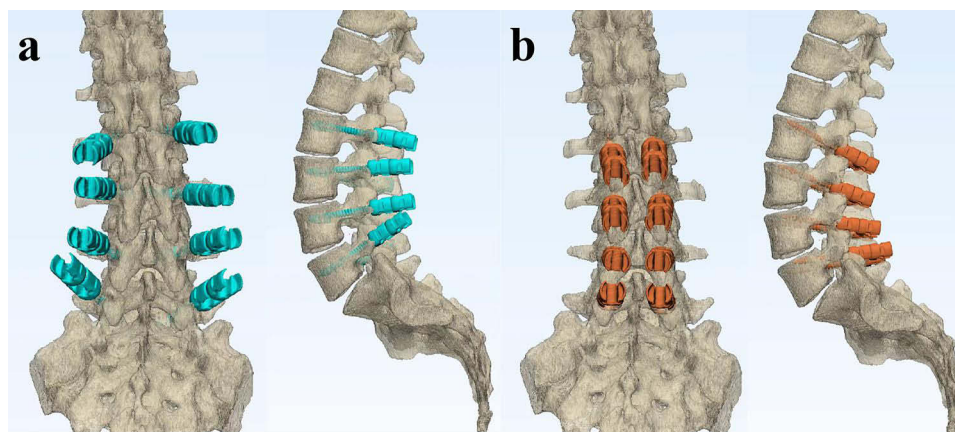


Figure 4 Pedicle screw placement (a); cortical bone trajectory screw placement (b).

Comparison of the Parameters of Scoliosis Between Two Groups

Table 4 shows that there was no significant difference in Cobb angle, lumbar lordosis (LL) angle, apex vertebral translation (AVT), coronal balance distance (CBD), and sagittal vertical axis (SVA) between the two groups preoperatively and during follow-up ($P > 0.05$).

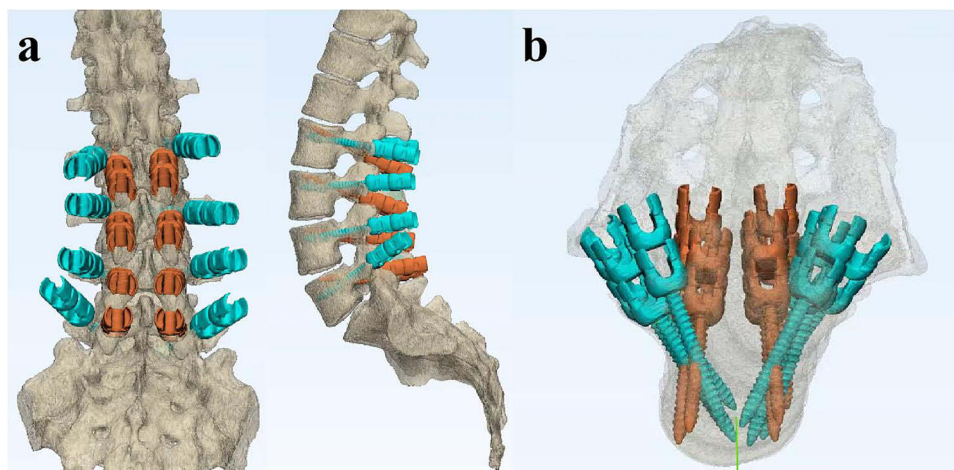


Figure 5 Comparison of two screws in anteroposterior and lateral position (a); Comparison of two screws in axial position (b).

Comparison of Complications Between Two Groups at 5-year Follow-up

Table 5 shows no significant difference in internal fixation fracture, cerebrospinal fluid leak, or cage settlement between the two groups during follow-up ($P>0.05$). The incidence of screw loosening and ASD in the CBT group was significantly lower than that in the PS group, and the difference was statistically significant ($P<0.05$).

Discussion

The surgical goals of ADS with stenosis are to relieve nerve compression, stabilize the decompression segment, restore coronal and sagittal balance, and prevent compensatory deformity of adjacent motor segments.^{15–17}

In recent years, the application of CBT screws in senile degenerative spinal diseases has gradually attracted attention.^{18–21} This study compared the efficacy of CBT and PS screws in ADS patients with LSS and found that the CBT group was significantly better than the PS group in terms of operation time, intraoperative blood loss, immobilization, and length of hospital stay. The low back VAS and ODI in the CBT group were significantly lower than those in the PS group at 6 months, 1 year, and 5 years postoperatively. The leg VAS in the CBT group was lower than that in the PS group at 5 years postoperatively, which may be related to the higher incidence of ASD in PS group. There were also no significant differences in scoliosis parameters between the two groups preoperatively and during follow-up. These results suggest that in ADS with stenosis, multi-level CBT screw fixation of the lumbar spine can achieve clinical efficacy comparable to PS fixation and shows potential advantages in reducing surgical trauma and accelerating recovery. CBT may be an effective alternative to PS in multi-level fixation, especially in cases with osteoporosis or requiring minimally invasive intervention.

The “cohesive” screw placement path of CBT reduces the dissection of paravertebral muscles, consistent with the reduction in intraoperative bleeding observed in this study. The CBT technique significantly reduced the risk of postoperative muscle atrophy by making smaller incisions and preserving polyfidus muscle attachment points, which explains the superior ODI at 6 months, 1 year, and 5 years postoperatively in the CBT group in this study.

Table 2 Comparison of Operation Time, Blood Loss, Immobilization and Length of Hospital Stay Between Two Groups

	PS Group	CBT Group	Statistics	P value
Operation time(h)	4.28±0.57	3.44±0.44	$t=5.20$	<0.05
Blood loss(mL)	713.18±86.87	535.26±47.54	$t=7.95$	<0.05
Immobilization(day)	5.23±1.02	3.74±1.05	$t=4.61$	<0.05
Length of hospital stay(day)	12.59±1.37	10.42±1.17	$t=5.41$	<0.05

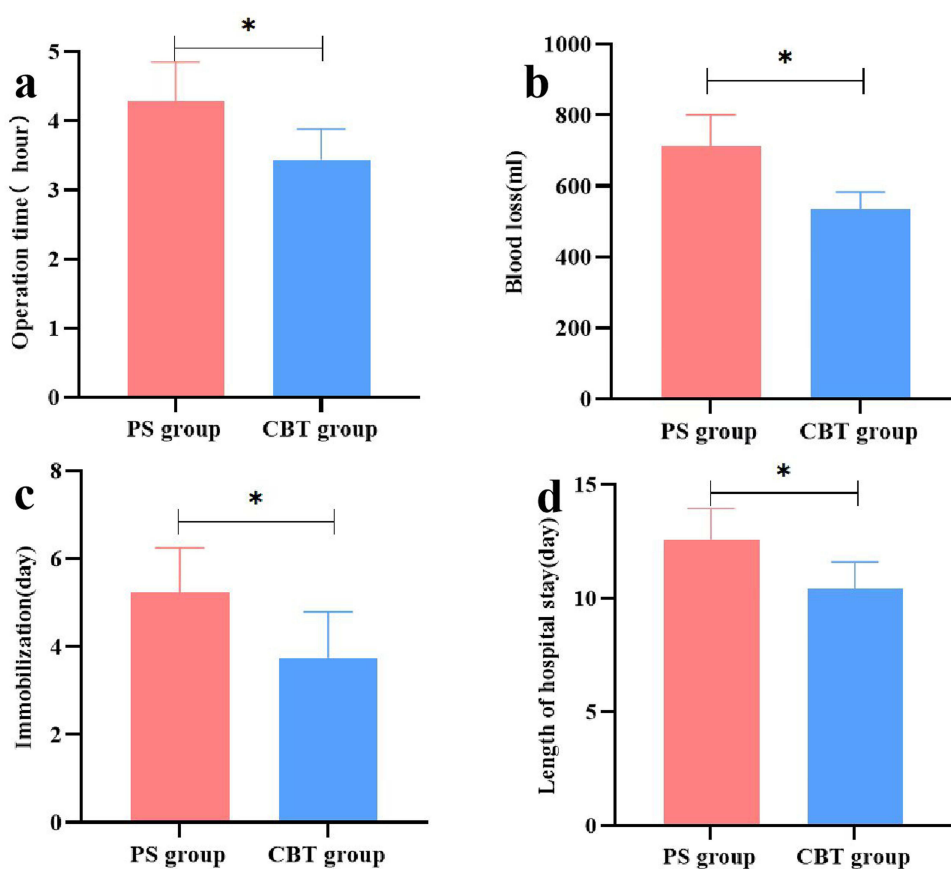


Figure 6 Comparison of operation time (a), blood loss (b), immobilization (c), and length of hospital stay (d) between two groups. Note: * $P < 0.05$.

ADS patients often have osteoporosis, and CBT's cortical bone anchoring properties are more advantageous in this population.^{22,23} CBT utilizes the mechanical properties of cortical bone in high-density areas to achieve stability by placing screws along the medial-lateral axis of the pedicle.²⁴⁻²⁶ Biomechanical studies showed that CBT had significantly higher pullout resistance than PS, especially for patients with decreased bone mineral density.²⁷ The rate of screw

Table 3 Comparison of Low Back VAS, Leg VAS, ODI Between Two Groups

Data Category	Time Period	PS Group	CBT Group	Statistics	P value
Low back VAS	Preoperatively	6.23±1.30	6.53±1.17	$t = -0.76$	0.44
	6 months postoperatively	3.64±1.04	2.79±0.97	$t = 2.66$	<0.05
	1 year postoperatively	2.59±1.14	1.79±0.97	$t = 2.39$	<0.05
	5 years postoperatively	3.59±1.56	1.68±1.05	$t = 4.49$	<0.05
Leg VAS	Preoperatively	6.73±1.03	6.58±1.17	$t = 0.43$	0.66
	6 months postoperatively	1.68±1.17	1.63±1.16	$t = 0.13$	0.89
	1 year postoperatively	1.82±1.14	1.58±1.21	$t = 0.65$	0.52
	5 years postoperatively	2.59±1.43	1.47±1.21	$t = 2.66$	<0.05
ODI (%)	Preoperatively	63.73±6.54	64.53±5.49	$t = -0.42$	0.67
	6 months postoperatively	34.64±5.93	28.42±6.16	$t = 3.28$	<0.05
	1 year postoperatively	21.55±4.13	12.53±6.82	$t = 5.01$	<0.05
	5 years postoperatively	27.18±4.92	11.68±7.69	$t = 7.54$	<0.05

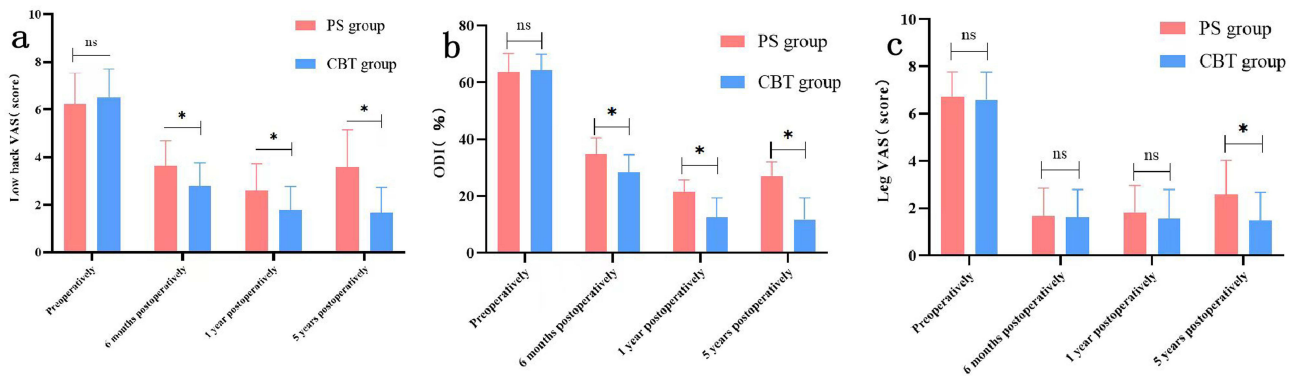


Figure 7 Comparison of low back VAS (a), ODI (b), and leg VAS (c) between two groups preoperatively and postoperatively. **Note:*** $P < 0.05$; ns-the difference was not statistically significant.

loosening in the CBT group was significantly lower than that in the PS group in this study, consistent with long-term follow-up results in most studies.^{18,28} During this more than 5-year follow-up period, no screw loosening occurred in the CBT group. The “Corticalization” phenomenon (Figure 1) was observed around the CBT in the CBT group, which may be related to the change of lumbar stress and the compensation of the human body itself. We suspect that the low rate of screw loosening is related to the advantage of CBT itself and to the “corticalization” phenomenon of screws, which greatly increases screw retention and allows better maintenance of decompression and correction. In the future, we will explain this “corticalization” phenomenon by increasing the sample size and follow-up time.

Because CBT screws were less resistant to rotation than PS, we included patients with ADS who had Cobb angle within 20° and vertebral body rotation within II degrees. Follow-up results showed that the CBT screw could achieve the same

Table 4 Comparison of Cobb, LL, Coronal Apical Deviation, Coronal Balance, Sagittal Balance Between Two Groups

Data Category	Time Period	PS Group	CBT Group	Statistics	P value
Cobb (°)	Preoperatively	15.83±1.92	16.45±1.66	$t = -1.10$	0.28
	6 months postoperatively	4.8±1.44	4.66±1.54	$t = 0.28$	0.78
	1 year postoperatively	4.97±1.42	4.86±1.56	$t = 0.22$	0.82
	5 years postoperatively	5.42±1.42	5.30±1.50	$t = 0.26$	0.79
LL (°)	Preoperatively	22.93±1.23	23.60±0.96	$t = -1.93$	0.06
	6 months postoperatively	33.56±1.94	33.28±1.77	$t = 0.48$	0.63
	1 year postoperatively	34.35±1.93	34.18±1.88	$t = 0.28$	0.77
	5 years postoperatively	37.91±2.16	36.57±2.33	$t = 1.89$	0.06
Coronal apical deviation (mm)	Preoperatively	14.51±1.04	15.07±0.90	$t = -1.83$	0.08
	6 months postoperatively	3.24±1.54	3.14±1.77	$t = 0.19$	0.84
	1 year postoperatively	3.45±1.55	3.37±1.79	$t = 0.13$	0.89
	5 years postoperatively	3.88±1.50	3.72±1.85	$t = 0.30$	0.76
Coronal balance (mm)	Preoperatively	10.87±2.25	12.01±2.16	$t = -1.64$	0.11
	6 months postoperatively	3.56±1.92	3.18±1.79	$t = 0.64$	0.52
	1 year postoperatively	2.44±1.72	2.32±1.73	$t = 0.21$	0.83
	5 years postoperatively	2.11±1.47	2.09±1.67	$t = 0.04$	0.96
Sagittal balance (mm)	Preoperatively	29.26±2.34	28.70±2.26	$t = 0.78$	0.44
	6 months postoperatively	16.48±1.67	16.41±2.36	$t = 0.10$	0.91
	1 year postoperatively	16.13±1.67	16.09±2.35	$t = 0.06$	0.94
	5 years postoperatively	14.44±1.52	14.14±1.30	$t = 0.65$	0.51

Table 5 Comparison of the Incidence of Complications Between Two Groups

	PS Group	CBT Group	Statistics	P value
Screw loosening (%)	27.3	0	–	<0.05
Adjacent segment degeneration (%)	22.7	0	–	<0.05
Internal fixation fracture (%)	4.5	0	–	0.53
Cerebrospinal fluid leak (%)	4.5	5.3	–	0.71
Cage settlement (%)	13.6	10.5	–	0.57

correction effect as PS for mild ADS. Lenke-Silva classification is instructive for the treatment of degenerative scoliosis.²⁹ The degenerative scoliosis patients included in this study were Lenke-Silva type II and III, and neither CBT nor PS required fixation to the thoracic spine. In both groups, the fixation level was lumbar (L2-5 or L1-5), which made it easier to observe proximal and distal ASD. The use of CBT screws in degenerative lumbar diseases has been shown to reduce the incidence of ASD compared with PS, which is inseparable from the biomechanical and minimally invasive advantages of CBT screws.^{30–32} However, previous studies have focused on short-level lumbar fixation. We first explored the use of long-level CBT in ADS, the results of which are consistent with previous studies of short-level lumbar fixation and can still significantly reduce the incidence of ASD. This provides a reference for future surgical treatment of mild ADS with stenosis.

Screw reinforcement materials are commonly used in clinical practice to enhance the fixation effect of pedicle screw and reduce the probability of screw loosening; common screw reinforcement materials include Polymethyl Methacrylate (PMMA), calcium phosphate, calcium sulfate, etc; pedicle screw with reinforcement materials can improve the axial pullout force of screws, especially in osteoporotic vertebral bodies.^{33–35}

Multi-level CBT screw fixation is a safe and effective treatment option for ADS with stenosis among the elderly, which has minimally invasive advantages and good biomechanical properties, especially suitable for osteoporosis patients. However, retrospective study and small sample size are limitations of this study, randomized controlled studies with larger sample sizes and longer follow-ups are needed to verify its long-term efficacy further.

Conclusion

Multi-segment cortical bone trajectory screws is a safe and effective option for mild adult degenerative scoliosis with stenosis among the elderly. This approach is less invasive and promotes faster recovery in this retrospective study, which can enhance long-term quality of life and decrease the risk of screw loosening and ASD. The clinical application time of CBT screws is still short, and large-scale prospective randomized controlled trials and long-term follow-up are lacking to confirm the safety and effectiveness of this surgical method.

Abbreviations

PS, pedicle screw; CBT, cortical bone trajectory; VAS, visual analog score; ODI, Oswestry Disability Index; LL, lumbar lordosis; AVT, apex vertebral translation; CBD, coronal balance distance; SVA, sagittal vertical axis; ASD, adjacent segment disease; ADS, adult degenerative scoliosis; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; PMMA, Polymethyl Methacrylate.

Data Sharing Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Ethics Approval and Informed Consent

The Ethics Committee of the Beijing Chaoyang Hospital of Capital Medical University approved the study, and written informed consent was obtained from participants prior to data collection. This study was conducted in accordance with the Declaration of Helsinki.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This work was supported by Clinical Research Incubation Program of Beijing Chao-Yang Hospital (CYFH202316).

Disclosure

The authors report no conflicts of interest in this work.

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