



# Clinical Comparison of Cortical Bone Trajectory and Percutaneous Pedicle Screw in Single-Level Minimally Invasive Lumbar Fusion

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## Abstract

**Object:** Percutaneous pedicle screws (PPS) have been widely used for posterior fusion. However, the osteoporotic spine in aging population leads to high rates of loosening. Recently introduced cortical bone trajectory (CBT) technique offers higher screw pullout strength and might be a solution to the problem. The aim of this study was to compare clinical outcomes of CBT vs. PPS in single level lumbar fusion.

**Methods:** We retrospectively reviewed 30 patients who received single-level posterior lumbar fusion with PPS (mean age 65 y.o.) and 30 patients with CBT (mean age 64 years). The procedures included TLIF (transforaminal lumbar interbody fusion) for L3 to L5 spondylolisthesis. The clinical outcomes were assessed with Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Oswestry Disability Index (ODI) and VAS (visual analogue scale) scoring. We also evaluated the rates of nonunion and screw loosening.

**Results:** There were no complications in both groups. The average operation time was significantly longer in the PPS group (p=0.02). The intraoperative blood loss was significantly greater in the PPS group (p=0.002). The average serum CRP (C - reactive protein) and CPK (creatin phosphokinase) level on POD1 (post-operative day 1) was significantly higher in the PPS group. The length of hospital stay was significantly longer for PPS group (p=0.03). Both groups showed significant improvement of JOABPEQ, ODI and VAS values at follow-up. The rate of screw loosening was statistically higher in the PPS group (p=0.009). Bony fusion rate was 90% in PPS group and 100% in CBT group (p=0.07).

**Conclusion:** CBT proved to be less invasive and a stronger anchor in one level lumbar fusion for degenerative lumbar spine disease.

## Introduction

Pedicle screw (PS) technique has been the mainstay anchor for posterior lumbar fusion for many years. The technique was further perfected when a percutaneous PS (PPS) was introduced which allowed for lesser soft tissue damage and postoperative pain. Outcomes of posterior lumbar fusion are strongly dependent on the achievement of bony fusion for which a stable instrumentation is a prerequisite. However, the osteoporotic spine in aging population leads to high rates of PS loosening [1]. The reason might be not only the low bone density and deteriorating bone quality but also the trajectory of PS which leads to the screw path passing through the weakest part of lamina cortex and into the osteoporotic cancellous bone of the pedicle and vertebral body with the screw tip lodging in the most osteoporotic center of the body in aged individuals. Recently introduced cortical bone trajectory (CBT) technique offers higher screw pullout strength and thus might be a solution to the problem [2-4]. The reason for higher pullout strength in CBT is that the insertion point is situated in the densest region of lamina and the screw pathway leads through the pedicle at a medio-laterally and caudo-cranially angulated trajectory which results in screw being wedged between inferomedial corner of the pedicle and the upper corner of the vertebral body. Finally the screw tip reaches the upper endplate and may even be advanced to purchase it or the latero-anterior bony spurs for better fixation. The screw thus is in intimate contact with cortical or subchondral bone so that cortical thread can be used. This trajectory gives reliable strength of

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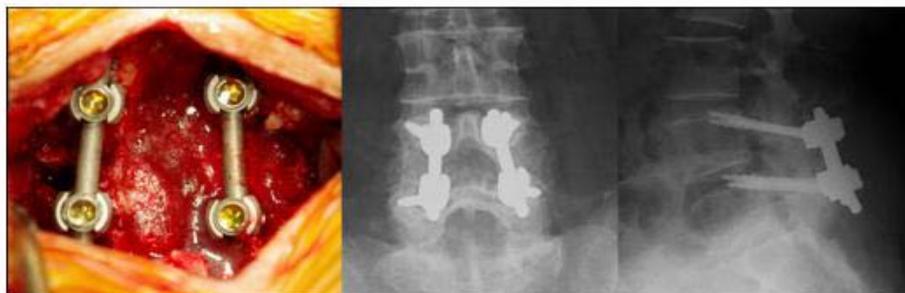
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**Figure 1:** MIS-PLF with CBT screws. View of final construct before bone grafting and postoperative X-rays.

**Table 1:** Background data comparison of two surgical groups.

	CBT	PPS	Significance
Number of cases	30	30	
Gender (M:F)	6:24	12:18	NS
Age	69 ± 9.9	66 ± 14	NS
BMI	24.7 ± 3.7	24 ± 4	NS
Smoker	3 cases	5 cases	NS
Previous lumbar surgery	5 cases	5 cases	NS
Preop ODI score (%)	45 ± 20	46 ± 16	NS
Preop % slip	13 ± 7	17 ± 5	NS
Age corrected Charson comorbidity index	2.8 ± 1.5	3 ± 1.5	NS
Duration of Symptoms (months)	29 ± 46	26 ± 63	NS

Mean ± SD

NS no significant difference between two groups

fixation even in the cases with compromised bone density because the cancellous not the cortical bone is most affected by osteoporosis. The CBT technique is very promising in cadaver studies but the clinical trials are yet very scarce. We retrospectively compared indicators of surgical invasiveness, clinical outcomes and rates of screw loosening and pseudarthrosis of single-level posterior spinal MIS (minimally invasive surgery) fusion using CBT vs. PPS techniques in a cohort of 60 patients at our center.

## Materials and Methods

### Patient demographics

Since December 2012 we have been using CBT screws for lumbar spine fusion. 30 patients who received posterior decompression with a single-level TLIF (transforaminal lumbar interbody fusion) were retrospectively selected for this study. The study was approved by the Ethics Committee of the Steel Memorial Muroran Hospital (approval number J160601). There were 24 L4 degenerative spondylolisthesis (DS), 4 L3 DS, one L4/5 discitis in remission and one L4/5 foraminal stenosis (FS) case.

Thirty consecutive cases operated with PPS during the same period were selected as a control group. The pathology was 12 L4 DS, 9 L3 DS, 1 L4 isthmic spondylolisthesis (IS), 7 L5 IS and 1 L4/5 FS case in this group. Both groups were matched for gender ratio, mean age, BMI, previous lumbar surgery, Charlson age corrected comorbidity index [5] and duration of symptoms. There was no significant difference in smoker/nonsmoker ratio, pre-op (preoperative) ODI score and pre-op % slip between the 2 groups (Table 1). All cases were followed up for at least one year post-op.

### Surgical procedures

The single-level lumbar fusion with CBT was performed through a single midline 4 cm incision with neural decompression by bilateral medial facetectomy. The screw insertion starting point was chosen on the medial aspect of pars interarticularis 2mm caudal at the 5 o'clock position as verified on AP (antero-posterior) C-arm image. After the starting point was created with a 3 mm surgical burr, the polyaxial CBT screws were inserted through a cranio-lateral trajectory as described by Santoni [2] and Mobbs [3]. The trajectory was chosen so that the screw tip would lodge in the upper corner of the vertebral body. TLIF with a PEEK cage was then performed after applying distraction directly to the CBT screw heads. This was followed by titanium rod application and final screw tightening in compression. The morcellated local bone mixed with artificial bone was used for bone graft (Figure 1).

The single-level MIS lumbar fusion with PPS was performed as previously described [6].

### Quantitative analyses of outcomes

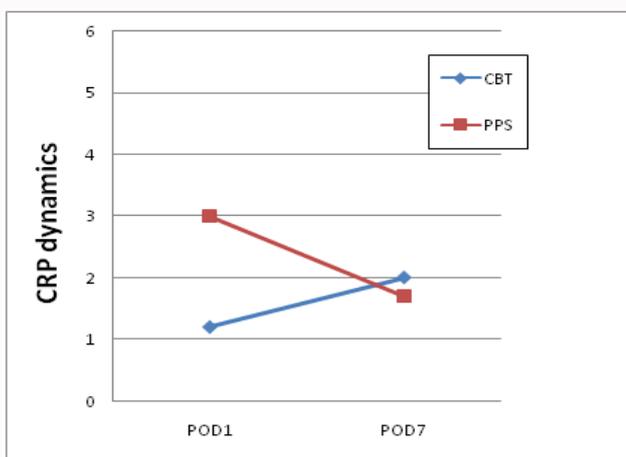
The surgical parameters of evaluation included operation time and intraoperative blood loss. Postoperative course was evaluated using CRP (C-reactive protein) and CPK (creatin phosphokinase) values on POD1 (postoperative day 1) and POD7. The Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ) [7], Oswestry Disability Index (ODI), Back Pain VAS (visual analogue scale), Leg Pain VAS, Lower Extremities Paresthesia VAS were used for clinical outcome appraisal. All the questionnaires were filled out by the patients without supervision by a physician. The JOABPEQ, ODI and VAS score were evaluated pre-op and at 6 months of follow up. The postoperative complications, length of hospital stay in days and discharge destination (home or rehabilitation facility) were registered for all cases. The loss of correction was evaluated by comparing % slip and slip angle values on pre-op (pre-operative), post-op and follow up X-rays. Screw loosening and fusion rates were evaluated by reviewing follow up CT scans.

### Statistical analysis

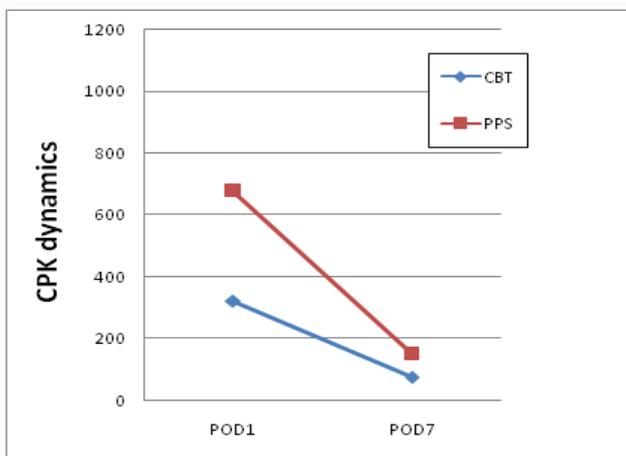
The interval data were compared using unpaired Student's t test between the 2 groups. The nominal data were compared using the Chi-square. The significance cutoff for both tests was set at  $p \leq 0.05$ .

## Results

All cases were followed up until at least one year post op. The average operation time was significantly longer in the PPS group ( $117 \pm 31$  min and  $137 \pm 26$  min in the CBT and PPS groups respectively,



**Figure 2:** Postoperative dynamics of mean CRP values for CBT and PPS groups. Asterisk depicts the statistically significant difference between the CBT and PPS groups (p=0.02).



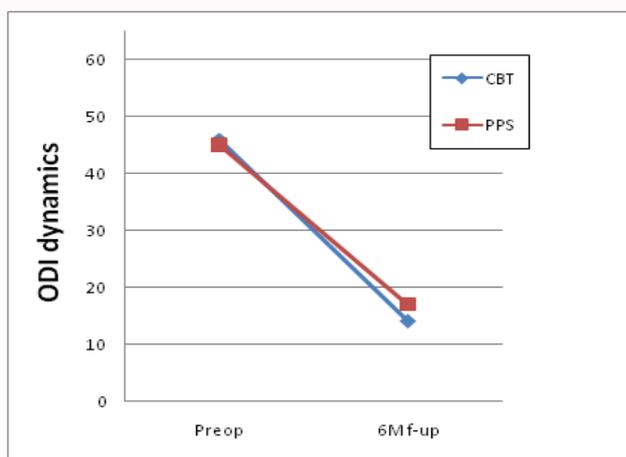
**Figure 3:** Postoperative dynamics of mean CPK values for CBT and PPS groups. Asterisk depicts the statistically significant difference between the CBT and PPS groups (p≤ 0.002).

**Table 2:** Comparison of JOABPEQ effectiveness ratios.

	CBT	PPS	Significance
Pain	86%	78%	NS
Function	64%	66%	NS
Walking	93%	78%	NS
Social	64%	78%	NS
Psychological	50%	45%	NS

NS no significant difference between two groups

p=0.02). The intraoperative blood loss was significantly greater in the PPS group (104 ± 72 ml and 280 ± 254 ml in the CBT and PPS groups respectively, p=0.002). The average serum CRP level on POD1 was significantly higher in the PPS group (1.2 ± 0.9 and 3.0 ± 2.5 in the CBT and PPS groups respectively, p=0.0008). The POD7 mean CRP values were not significantly different (2.1 ± 2.0 and 1.7 ± 1.1 in the CBT and PPS groups respectively, p=0.3). The POD1 mean CPK level was significantly higher in the PPS group (322 ± 358 and 679 ± 410 in the CBT and PPS groups respectively, p=0.001). The POD7 mean CPK level was significantly higher in the PPS group (74 ± 37



**Figure 4:** The ODI score dynamics.

and 151 ± 129 in the CBT and PPS groups respectively, p=0.002). The CPK levels in the CBT group showed faster decrease (Figure 3). The length of hospital stay was significantly longer for PPS group (16 days for PPS vs. 13.6 days for CBT, p=0.03). Significantly more patients in the PPS group required a transfer to a rehabilitation facility after discharge (9 in PPS group vs. 3 in CBT group, p=0.05).

The average JOABPEQ effectiveness ratios were not statistically different with best levels of effectiveness demonstrated for pain and walking and lowest effectiveness for psychological disability (Table 2).

The mean preoperative ODI scores were 46% and 45% in the PPS and CBT groups respectively which were statistically not different (Table 1). The mean follow-up ODI scores decreased dramatically in both groups to 17% and 15% in the PPS and CBT groups respectively which were also statistically not different between groups (Figure 4). The mean preoperative low back pain (LBP) VAS scores were 69.1 and 69.2 in PPS and CBT groups respectively. At follow up the mean LBP VAS scores were 19.4 and 10.5 in PPS and CBT groups respectively (p=0.1) (Figure 5). The mean preoperative leg pain VAS scores were 65.5 and 73.9 in PPS and CBT groups respectively. At follow up the mean leg pain VAS scores improved to 17 and 8.8 in PPS and CBT groups respectively (p= 0.1) (Figure 6). The mean preoperative low extremity paresthesia VAS scores were 66 and 65 in PPS and CBT groups respectively. At follow up the mean low extremity paresthesia VAS scores improved to 10.6 and 8.8 in PPS and CBT groups respectively (p=0.7) (Figure 7). No statistically significant differences were observed between any preoperative or follow up VAS scores between the PPS and CBT groups.

Losses of correction were evaluated by measuring % slip and slip angles on post-op and follow up radiographs. The mean pre-op % slip was 17% and 13% in PPS and CBT groups respectively, which was not statistically different. Mean % slip was corrected to 5.7% and 2.6% on post-op films in PPS and CBT groups respectively. On follow up films mean % slip degenerated to 16% and 5% in PPS and CBT groups respectively with mean % slip loss of correction as large as 10% in PPS and only 2% in CBT group (p=0.0001) (Figure 8).

The mean pre-op slip angle was -12 deg (lordosis) in PPS and -7.2 deg (lordosis) in CBT group, which were not significantly different. The mean slip angles were corrected to -16 and -7.6 deg on post-op films in PPS and CBT groups respectively. On follow up films

mean slip angle changed to -12 and -6.7 deg in PPS and CBT groups respectively with mean slip angle loss of correction as large as 5.2 deg in PPS and only 2.3 deg in CBT group ( $p=0.0001$ ) (Figure 9).

The presence of pseudarthrosis and screw loosening was evaluated on the follow up CT scans. Screw loosening was observed in 6 patients (20% of cases) in PPS group and in 0 cases in CBT group ( $p=0.009$ ). Bony fusion was achieved in 27 cases in PPS group (90%) and in 30 cases in CBT group (100%). This difference was not statistically significant by Chi-square ( $p=0.07$ ). Two pseudarthrosis in PPS group required revision with CBT screws and eventually achieved fusion and one case was asymptomatic (Figure 9). There was one case of deep hematoma formation requiring evacuation in the PPS group and no major complications, such as CSF leak, deep hematoma or deep wound infection in the CBT group.

## Discussion

The CBT technique for posterior lumbar spine instrumentation has been growing popular in recent years [8,9]. There are substantial anatomical cadaveric [2,4] and *in vivo* [3] studies supporting its effectiveness. However, to our knowledge, as of yet, there are few papers reporting the outcomes of posterior lumbar fusion with CBT screws in human subjects. We could locate one case report of CBT use in a long construct in combination with PS leading to a favorable result [6]. We used CBT trajectory to insert screws for single segment posterior lumbar fusion with TLIF. The operation was performed through a single midline incision after spinal canal decompression with medial facetectomy. Local bone mixed with hydroxyapatite grafted to achieve fusion. We compared the parameters of surgical invasion and clinical and radiological outcomes of the new CBT procedure with the previously established MIS lumbar fusion with PPS [6]. We found out that operation time was significantly longer in the PPS group that might be explained by more time consuming rod introduction through a percutaneous route, time needed for image intensifier manipulation during the PPS insertion, longer time needed for neural decompression through a smaller incision. The intraoperative bleeding was also significantly greater in the PPS group which could be explained by incisions through the muscle tissue for PPS insertion as opposed to single midline incision in the CBT group with only minimal muscle tissue violation.

Postoperative day one CRP and CPK values were both significantly higher in the PPS group which could be accounted for by the additional invasion of the additional incisions through the paravertebral muscles for the PPS insertion in the PPS group as opposed to paravertebral muscle preservation achieved with the medial incision required for the CBT insertion. Less muscle damage probably also accounts for lower POD7 levels of CPK and faster CPK subsidence in the CBT group. Despite the mean preoperative Charlson comorbidity indices, BMI, duration of symptoms, previous low back surgery, ODI and VAS scores being not different between the PPS and the CBT group, patients in the CBT group were discharged from the hospital significantly faster and significantly more of these patients returned home after discharge compared to the PPS group who needed longer hospital stays and prolonged rehabilitation. This might be partially explained by overall milder surgical invasion of the CBT procedure as seen from the shorter operation time, and less intraoperative bleeding. The better fixation achieved with CBT might be another contributor to the faster recovery of the patients in the CBT group. The higher torque of the CBT screws compared to traditional PS was previously reported in cadaveric and *in vivo* studies

[2-4]. By reviewing the follow up films we found out that loss of correction for both % slip and slip angle were significantly greater in the PPS group compared to the CBT. This might be explained by the ability of the CBT screws to prevent the notorious windshield wiper motion phenomenon due to the inherent features of the cortical bone trajectory which places the screw in intimate contact with the cortical bone from all sides. Also there is a great extent of possible variations for the cortical bone trajectory itself that allows for selective screw placement into the areas of the highest bone density especially when used with intraoperative navigation. We observed screw loosening in 20% of PPS cases and pseudarthroses in 10% of PPS cases while there was no incidence of screw loosening or pseudarthrosis in the CBT group. This difference might have resulted from the better fixation achieved with CBT screws.

During the operation the distractor can be directly applied to the CBT screw heads without risk of loosening or cutout because of the sufficient anchoring strength of CBT screws. This allows for better intraoperative reduction of the slipped vertebra. Such reduction is impossible when PS is used because of high incidence of loosening.

## Conclusion

Overall, compared to PPS, single level lumbar fusion with CBT screws proved to be associated with less surgical invasion, better clinical results (faster hospital discharge with less need for rehabilitation), better spondylolisthesis correction with less loss of correction and screw loosening in our study. CBT screws were also successfully utilized during revisions for pseudoarthroses after instrumentation with PPS. In those cases there was no need for any augmentation or bone packing into the screw tract because the CBT trajectory avoids the PS screw hole and sufficient bone stock is available for screwing even after PS removal. More research is mandatory, however, to elucidate whether CBT screws will perform as well in multiple level lumbar fusion, to what extent can CBT be used in the lower thoracic spine, can CBT screws be successfully inserted percutaneously, can CBT screws be successfully aligned for rod application in a thoracolumbar fusion construct with PSs. Also higher anchoring strength of the CBT screws might lead to higher rate of implant failure such as screw or rod breakage which should become clear in a larger cohort with a longer follow up period.

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