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Comparison of Clinical Outcomes of Cortical Bone Trajectory and Traditional Pedicle Screw Fixation in Posterior Lumbar Interbody Fusion

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Abstract

Posterior lumbar interbody fusion (PLIF) is a common surgical procedure and widely used in the treatment of lumbar degenerative disc disorders. Traditionally, posterior lumbar interbody fusion is done by using the traditional pedicle screw (PS) which offers great advantages, but at the same time it has some disadvantages which include the risk of superior facet joint violation and muscle damage. Recently, an alternative method of screw insertion via cortical bone trajectory (CBT) has been invented which has less invasive process and can be placed without the drawbacks associated with the traditional pedicle screw. However, it has to remain an interest whether CBT will provide similar or greater clinical outcomes compared to PS in PLIF. So the main aim of this review is to compare the clinical outcomes of cortical bone trajectory and traditional pedicle screw fixation in posterior lumbar interbody fusion based on the articles published on this topic. Compared to the traditional pedicle screw fixation, PLIF with CBT has similar clinical outcome based on pain intensity, ODI status and JOA score, as well as similar fusion rate and radiological evaluated complication such as loosening of screw. In addition PLIF with CBT has advantages of less facet joint violation, less blood loss, less intraoperative muscle damage and perioperative pain. On the basis of this study, we can suggest that PLIF with CBT can be considered as a reasonable alternative to PS in PLIF.

Keywords

Posterior Lumbar Interbody Fusion, Cortical Bone Trajectory, Traditional Pedicle Screw Fixation, Cortical Screw, Pedicle Screw

1. Introduction

The posterior lumbar interbody fusion is the lumbar fusion technique in which the disc space is exposed from the posterior approach similar to that used in a discectomy and fusion is performed by directly grafting the intervertebral disc [1]. The posterior lumbar interbody fusion (PLIF) technique has become the integral part among the spine surgeon in these modern days. This technique was performed routinely by only few surgeons due to its technical difficulties [2] [3]. In recent days PLIF surgery with the pedicle screw (PS) is used to treat certain lumbar pathologies such as spondylolisthesis, spinal disc herniation, spinal disc degeneration and the spine instability [4] [5] [6]. PLIF with PS has become the irreplaceable technique in the fusion surgery for the lumbar pathologies due to its numerous advantages [7] [8] [9]. The traditional insertion pathway for pedicle screws involves a transpedicular lateral to medial trajectory with the initial insertion point at the junction of the transverse process and lateral wall of facet [10]. However, the use of PLIF with PS include the risk of violation of superior facet joint in course of screw placement, the long incision length, iatrogenic muscle damaged due to PS insertion point and persistent postoperative low back pain [11] [12]. In spite of lack of alternative technique, spine surgeon has continued using PLIF with PS even though it has certain drawbacks. However, advances in the spine surgery and a more general trend towards the adoption of less invasive procedure have led to the development of new and innovative techniques, which aim to achieve spinal fixation while causing less damage to surrounding tissues [13] [14].

In 2009, Santoni *et al.* reported cortical bone trajectory (CBT) as a new alternative technique for inserting the pedicle screw in the lumbar spine to obtain the more solid fixation. The screws followed a lateral path in the axial plane and caudocephalad path in the sagittal plane in cortical bone trajectory (CBT). Their study on cadaver demonstrated that the new cortical trajectory and screw design had equivalent pullout and toggle characteristics and that 30% uniaxial yielded pullout in comparison to the traditional pedicle screw [15]. In contrast to the traditional pedicle screw fixation, CBT screws do not penetrate the vertebral body trabecular space [15]. Several biomechanical studies have also reported the insertional torque of cortical screw (CS) is greater than the pedicle screw and has similar results in terms of other biomechanical properties [16] [17] [18] [19]. Since the cortical screw is inserted at the junction of the superior articular process and pars, it limits the incision length of superior facet joint and reduces the damage of paraspinal muscle [20]. Some of the studies [21] [22] [23] have shown that the use of CBT has more benefits than the use of PS and other studies [24] [25] [26] have different outcomes. However, it is still unclear whether to use CBT or PS technique as gold standard for the treatment of the lumbar pathologies. So, in this review we tried to compare the clinical outcome of posterior lumbar interbody fusion (PLIF) using the CBT technique and PLIF using the traditional PS technique based on the articles published on this topic.

2. Surgical Technique

2.1. CBT Technique

In cortical bone trajectory technique a posterior midline skin incision is made at the fusion level. Then the paraspinal muscle and lamina at the fusion segment is elevated. Dissection of facet joint at the level of the fusion segment is done but the facet joint one level above the fusion segment is not dissected to achieve the minimal invasiveness [27]. Decompression was achieved by laminectomy or facectectomy. Then the intervertebral disc is removed and polyetheretheketone cage packed with the bone graft is inserted on the space. The residual bone grafts are inserted lateral to the cage [28]. Then the screw is inserted at the junction between the lateral pars interarticularis and superior articular process (1 mm inferior to the inferior border of the transverse process, which was projected to the 5 o'clock orientation in the left pedicle and 7 o'clock orientation in the right pedicle) and rod are fixed [29] [30]. The cephalad screw is directed in a caudal to cephalad in the sagittal plane and medial to lateral in the axial plane [15] (**Figure 1**).

2.2. Traditional PS Fixation Technique

In case of conventional PS technique the posterior midline skin incision (larger than in CBT) is made at the fusion level. Then the paraspinal muscle and facet joints are incised including the facet joint 1 level above the fusion level is also exposed [27] [28]. The decompression and the placement of the polyethereketone cage with the bone grafts are done same as in CBT technique. The pedicle screw is inserted at the junction between the mid transverse process and lateral aspect of superior facet joint and the rod are fixed [31] [32]. The pedicle screw is

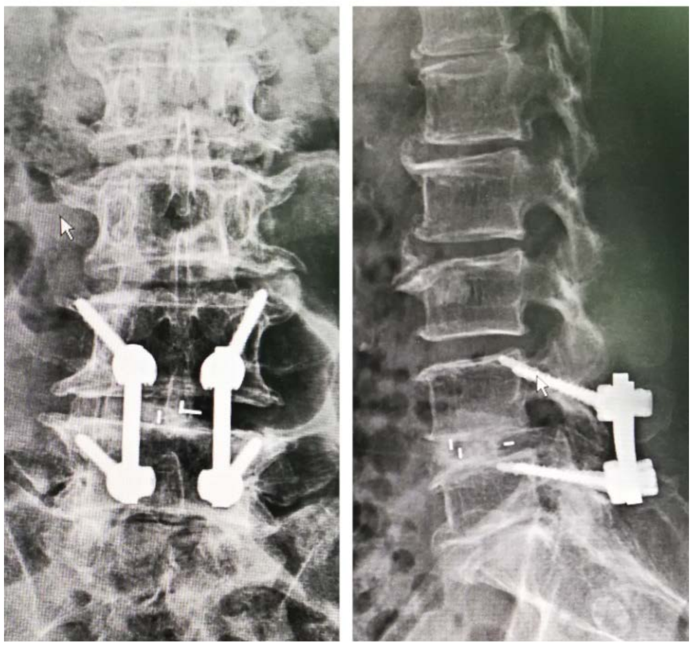

Figure 1. Plain radiograph showing anteroposterior and lateral view in CBT group (image taken from Zhongda Hospital).

directed in a lateral to medial trajectory through the pedicle and vertebral body [30] [33] (**Figure 2**).

3. Clinical Evaluation

There are various methods used for the clinical evaluation in the treatment of the lumbar pathologies using the fusion surgery. Generally the clinical evaluation is done by using the Visual analog scale (VAS score), Oswetry disability index (ODI score) and Japanese orthopedic association score of low back pain (JOA score).

3.1. Visual Analog Scale (VAS Score)

A visual analog scale is a measurement instrument for the subjective characteristic or attitude which cannot be directly measured and is believed to range between a continuum of values. VAS usually has a horizontal line, 100 mm in length with word descriptor anchored by no pain (score 0) and the worst imaginable pain (score 100). The patient is asked to mark on the line the point they feel which represent their perception of pain and categorized as no pain, mild pain, moderate pain or severe pain [34].

3.2. Oswetry Disability Index (ODI Score)

The oswetry disability index (also known as the oswetry low back pain disability questionnaire) is an important tool used by the clinicians and researchers to measure the patient's permanent functional disability for the low back pain. It is considered as the gold standard for degree of disability in person with low back

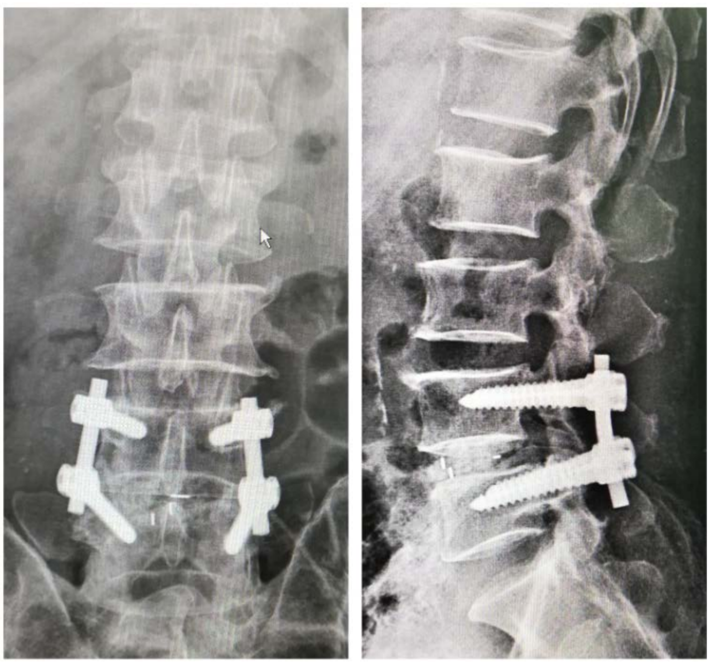

Figure 2. Plain radiograph showing anteroposterior and lateral view in PS group (image taken from Zhongda Hospital).

pain [35]. Questionnaire examines perceived level of disability in 10 everyday activities of daily living which include intensity of pain, lifting, ability to care for oneself, ability to work, ability to sit, sexual function, ability to stand, social life, sleep quality and ability to travel [36]. Then each category is followed by 6 statements which are scored from 0 to 5. The statement being zero indicates the least amount of disability and the scored 5 indicate the most severe disability [36]. The scores for all questions answered are summed, then multiplied by two to obtain the index which ranges from zero (no disability) to 100 (maximum disability possible). Then it is categorized as minimal disability (0 to 20), moderate disability (21 to 40), severe disability (41 to 60), Crippled (61 to 80) and the patient that are either bed bound or exaggerating their symptoms (81 to 100) [36].

3.3. Japanese Orthopedic Association (JOA) Score for Low Back Pain

In 1986 the Japanese orthopedic association developed and brought the specific measures for the evaluation of the low back pain back called JOA score. It has been widely used to evaluate the clinical status of different type of intervention in patients with the low back pain [37]. The JOA score for the low back pain include the assessment of the subjective symptoms (low back pain, leg pain and/or tingling, gait), clinical signs (leg raising test, sensory disturbance, motor deficit), restriction of daily living activities (turn over while lying, standing, washing, leaning forward, sitting, lifting or holding heavy object, walking) and urinary bladder function. The total JOA score for low back pain in healthy population is 29 [38].

4. Review of Literature

The reviews of various original articles were done focusing on posterior lumbar interbody fusion, cortical bone trajectory and traditional pedicle screw fixation method. The article search was done on different search engine such as PUBMED, SCOPUS, GOOGLE SCHOLAR and RESEARCH GATE by using the search word posterior lumbar interbody fusion, cortical bone trajectory, cortical screw, pedicle screw and traditional pedicle screw fixation (**Figure 3**).

Around 80 articles related to the lumbar spine surgery were studied of which 28 articles were extracted which were either related to PLIF, CBT or PS. Out of 28 articles only 8 articles were extracted which were related to the comparison between the cortical bone trajectory and traditional pedicle screw fixation in PLIF. Among them 2 articles were excluded as they did not provide direct clinical comparison between the CBT and PS in PLIF. Finally, we have 6 articles which focus on the comparison of clinical outcome between the CBT and PS in PLIF based on VAS score, ODI score or JOA score (**Table 1**).

4.1. Lee, Son, Kim *et al.* 2015 [25]

In this prospective, randomized, non-inferiority trial 79 patient were assigned to

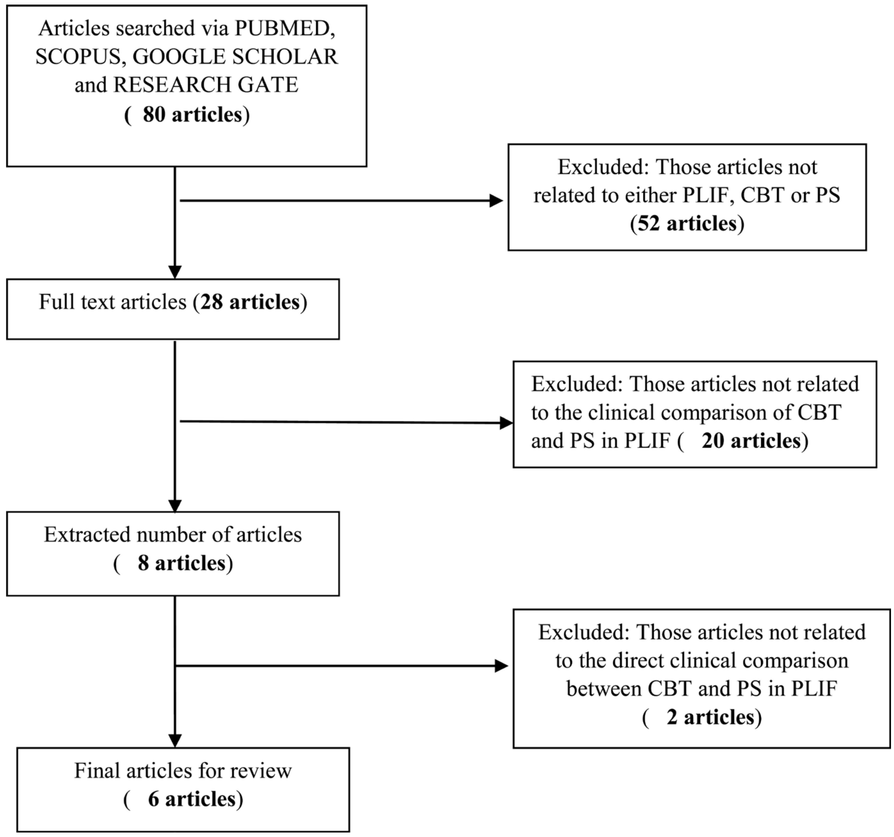

Figure 3. Flowchart showing the article selection process included in the review.

the group A (39 patients) for which PS was used and group B (40 patient) for which CS was used. In group B 2 patient was lost during follow up and only 38 patients were qualified for the study. The similar fusion rate was found in both group ($p = 0.81$ and 0.61 respectively) at the 6 and 12 months follow up. The mean VAS score for the low back pain was 7.6 ± 3.1 pre operatively to 2.0 ± 0.1 at postoperative 1 year in group A and from 7.7 ± 3.1 pre operatively to 2.1 ± 1.5 at postoperative 1 year in group B ($p = 0.38$) which indicate no significant difference between the group. But the VAS score for the low back pain at postoperative week one was 4.3 ± 2.1 for group A and 2.4 ± 1.3 for group B ($p = 0.02$) which indicate the significant difference. The VAS score for radiating pain also improved significantly on both groups, with mean score decreasing from 5.7 ± 1.8 preoperatively to 1.1 ± 0.4 at postoperative 1 year in group A and from 5.9 ± 1.3 to 1.2 ± 0.6 in group B but no significant difference between the two groups ($p = 0.67$). The mean ODI score was 36.5 ± 10.1 preoperatively to 11.0 ± 2.5 after one year of surgery in group A and from 35.1 ± 9.7 preoperatively to 10.5 ± 2.8 after one year of surgery in group B. The ODI score was improved on both the groups but has no significant difference between the two group ($p = 0.46$). In terms of operative time, intraoperative blood loss and incision length, group B had better outcome than group A. Facet joint violation occurred in 7 of 39 patients (18%) in group A and 0 of 38 patient in group B which shows significant difference between the groups ($p < 0.01$). Malpositioned screw was seen on 2

Table 1. Summary of clinical outcome of the included study.

Source and publication year	Year of study	Study design	No. of patient		Follow-up	Clinical evaluation based on VAS score, ODI score and JOA score.	Conclusion
			CBT	PS			
Lee, Son, Kim *et al.* (2015)	_	Prospective study	38	39	1 year	VAS score for the low back pain and radiating pain was decreased from 7.6 ± 3.1 and 5.7 ± 1.8 preoperatively to 2.0 ± 0.1 and 1.1 ± 0.4 postoperative in PS group and from 7.7 ± 3.1 and 5.9 ± 1.3 preoperatively to 2.1 ± 1.5 and 1.2 ± 0.6 at postoperative in CBT group (p = 0.38) for back pain and p = 0.67 for radiating pain). ODI score was decreased from 36.5 ± 10.1 and 35.1 ± 9.7 preoperatively to 11.0 ± 2.5 and 10.5 ± 2.8 postoperative in PS group and CBT group respectively (p = 0.46). But the VAS score for the low back pain at postoperative week one was 4.3 ± 2.1 for PS group and 2.4 ± 1.3 for CBT group (p = 0.02).	Both the ODI score and VAS score showed no significant difference between the two groups. However VAS score for low back pain at postoperative week 1 is significantly low in CBT group.
Sakura, Miwa, Yamashita *et al.* (2016)	Since Nov 2011 for CBT group and before Oct 2011 for PS group	Cohort study	95	82	35 months (CBT group) 40 months (PS group)	There was significant improvement in the JOA score from 13.7 preoperative to 23.3 postoperative final follow up in CBT group (mean recovery rate 64.4%) in comparison with 14.4 points before operation to 22.7 points at latest follow up in PS group (mean recovery rate 55.8%, p < 0.05).	There was no significant difference between the JOA score between two groups; however recovery rate is higher in CBT group.
Hung, Wu, Kao *et al.* (2016)	May 2013-Jan. 2014	Retrospective study	16	16	18 months	VAS score for the back pain and leg pain was 6.87 ± 1.26 and 7.60 ± 2.06 preoperative to 1.25 ± 0.96 and 0.05 ± 0.55 postoperative in CBT group and 6.67 ± 2.87 and 7.60 ± 2.06 preoperative to 1.08 ± 1.11 and 0.15 ± 0.55 postoperative follow up in PS group. ODI score was 31 ± 4.95 preoperative to 5.5 ± 1.71 postoperative follow up in CBT group and 26.16 ± 8.92 preoperative to 5.84 ± 4.43 postoperative follow up in PS group. The JOA score was 11 ± 4.24 to 27 ± 2.16 (recovery rate = 76.20%) in postoperative follow up in CBT group and 17.64 ± 8.30 to 25.77 ± 1.92 (recovery rate = 67.21%) in PS group.	The VAS Score for back and leg pain, ODI score and JOA score improved in both groups postoperatively but showed no significant difference between the two groups.
Lee and Ahn (2017)	_	Prospective randomized study	35	37	2 years	VAS score for low back pain and radiating pain decreased from 7.6 ± 3.1 and5.7 ± 1.8 preoperatively to 2.9 ± 1.1 and 1.8 ± 0.6 1 at 2 year postoperatively in PS group and from 7.7 ± 3.1 and 5.9 ± 1.3 to 2.7 ± 0.8 and 1.3 ± 0.7 in CBT group (p = 0.67 for back pain and p = 0.35 for radiating pain). The mean ODI score was also improved on both group from 36.5 ± 10.1 to 13.6 ± 4.9 at 2 year postoperatively in PS group and from 35.1 ± 9.7 preoperatively to 11.8 ± 6.2 at 2 years postoperatively in CBT group.	The VAS Score for back and leg pain as well as ODI score improved in both groups postoperatively but showed no significant difference between the two groups.

Continued

Marengo, Ajello, Pilloni *et al.* (2017)	Jan 2015 to Mar 2016	Prospective cohort study	20	20	1 year	VAS score for lower back pain was significantly decreased from 8.6 (SD1.19) preoperatively to 1.95 (SD1.47) postoperative in CBT group and 8.25 (SD1.27) preoperatively to 2.85 (SD1.31) postoperative in PS group ($p < 0.001$). At final follow up the mean ODI score in CBT group was decreased from 68% ± 37% to 9% ± 10% and from 58% ± 15% to 23% ± 9% in the PS group ($p = 0.0150$).	Both the VAS score and the ODI score shows significantly lower in CBT group.
Sakura, Miwa, Kuroda *et al.* (2018)	Nov 2011 to Sept 2013 for CBT group and Aug 2009 to Oct 2011 for PS group	Cohort study	22	20	39 months	There was significant improvement on mean JOA score from 12.3 points preoperative to 21.1 points (mean recovery rate 54.4%) on final follow up in CBT group compared to 12.8 points pre-operative to 20.4 points (mean recovery rate 51.8%) on final follow up on PS group ($p > 0.05$).	No significant difference was found in the JOA score before and after the surgery between the two groups.

patients in group A on postoperative CT scan. There were no postoperative complications for any patient; however, there was superficial wound infection at surgical site on 1 patient in group A which was resolved after wound debridement.

4.2. Sakura, Miwa, Yamashita *et al.* 2016 [28]

Ninety five patient since November 2011 was undergone PLIF with CBT screw fixation for degenerative spondylolisthesis (CBT group) and 82 patient before October 2011 was undergone PLIF with the traditional PS fixation (PS group). There were 46 men and 49 women with mean age of 68.7 year in CBT group and 36 men and 46 women with mean age of 67 years in PS group. The mean operative time was 123 ± 24 minutes in CBT group and 145 ± 33 minutes in PS group. The average blood loss was 205 ± 152 ml in CBT group and 204 ± 145 ml in PS group. There was significant improvement in the JOA score from 13.7 points preoperative to 23.3 postoperative final follow up in CBT group (mean recovery rate 64.4%) in comparison with 14.4 points before operation to 22.7 points at final follow up in PS group (mean recovery rate 55.8%, $p < 0.05$). The solid spinal fusion was found in 84 out of 95 patients in CBT group (fusion rate 88.4%) and 79 out of 82 patient in PS group (fusion rate = 96.3%). The fusion rate seemed to be higher on PS in comparison to CBT group but wasn't statistically significant ($p = 0.052$). Three patients in CBT group (3.2%) and 9 patient in PS group (11.0%) developed symptomatic adjacent segment disease (ASD). All needed surgery for symptomatic ASD because of unresponsiveness to conservative treatment. Seven patients from CBT group (7.4%) and 8 patient from PS group (9.8%) developed early surgery related complication (such as dural laceration, hematoma, misplacement of screw and wound infection except ASD). There was no significant difference in the incidence of early surgery related complication among two groups.

4.3. Hung, Wu, Kao *et al.* 2016 [39]

This is a prospective study with the 16 patients underwent PLIF with CBT and 16 patients underwent conventional PLIF between the May 2013 and January 2014. The patient follow up period was 18 months. The operation duration, intraoperative blood loss and hospital stay was 3.96 ± 1.05 hrs, 218.18 ± 78.33 ml and 5.19 ± 1.42 days respectively in CBT group and 4.43 ± 1.42 hrs, 272.50 ± 78.08 ml and 5.81 ± 0.54 respectively in PS group which shows no significant difference between the two groups. The VAS score for the back pain was 6.87 ± 1.26 preoperative to 1.25 ± 0.96 postoperative follow up in CBT group and 6.67 ± 2.87 preoperative to 1.08 ± 1.11 postoperative follow up in PS group. The VAS score for leg pain was 7.60 ± 2.06 preoperative to 0.05 ± 0.55 postoperative in CBT group and 7.60 ± 2.06 preoperative to 0.15 ± 0.55 postoperative in PS group. The mean ODI score was 31 ± 4.95 preoperative to 5.5 ± 1.71 postoperative follow up in CBT group and 26.16 ± 8.92 preoperative to 5.84 ± 4.43 postoperative follow up in PS group. The JOA score was 11 ± 4.24 to 27 ± 2.16 (recovery rate = 76.20%) in postoperative follow up in CBT group and 17.64 ± 8.30 to 25.77 ± 1.92 (recovery rate = 67.21%) in PS group. The VAS score for back and leg pain, ODI score and JOA score improved in both groups postoperatively but showed no significant difference between the two groups.

4.4. Lee and Ahn 2017 [40]

Originally 79 patients were enrolled and divided into two groups (39 patients in group A with PS and 40 patients in group B with CS) and single level posterior lumbar interbody fusion was done. 7 patients were lost in the follow up and remained 72 patients (37 in group A and 35 in group B) were studied. It was prospective study with the follow up of 2 years. After 2 years of post-surgery the solid fusion were achieved in 35 of 37 patients (94.5%) in group A and 33 of 35 patients (94.3%) in group B, which was not significant among the two group ($p > 0.99$). At the 2 year postoperative the mean VAS score for lower back pain was lower than the preoperative level in both group, with mean score decreased from 7.6 ± 3.1 preoperatively to 2.9 ± 1.1 at 2 year postoperatively in group A and from 7.7 ± 3.1 to 2.7 ± 0.8 in group B ($p = 0.67$. The mean VAS score for radiating pain also decreased from 5.7 ± 1.8 preoperatively to 1.8 ± 0.6 1 year postoperatively in group A and from 5.9 ± 1.3 to 1.3 ± 0.7 in group B ($p = 0.35$). The mean ODI score was also improved on both groups from 36.5 ± 10.1 to 13.6 ± 4.9 at 2 year postoperatively in group A and from 35.1 ± 9.7 preoperatively to 11.8 ± 6.2 at 2 years postoperatively in group B. But there was no significant difference between the two groups. The sign of screw loosening was observed (19%) in group A and 4 of 35 patients (11.4%) in group B ($p = 0.51$) on CT evaluation at 2 year. At 2 years follow up, 8 of 37 patients (21.6%) in the PS group and 4 of 35 patients (11.4%) in CS group was found with recurrent radiating pain to the lower extremity with no significant difference between the two groups.

4.5. Marengo, Ajello, Pilloni *et al.* (2018) [41]

In this study 40 patients with mono segmental degenerative disease were treated from January 2015 to March 2016 by dividing into two groups (20 patients went to PLIF with CBT and 20 patients went to PLIF with PS). The prospective study was done with the follow up for one year. After one year of surgery, solid fusion was achieved in 18 out of 20 patients (90%) in the CBT group and in 17 out of 20 patients (85%) in the PS group. However the difference in the fusion rate was not significant ($p = 0.3292$). The mean VAS score for lower back pain was significantly decreased from 8.6 (SD 1.19) preoperatively to 1.95 (SD 1.47) at 1 year postoperatively in CBT group and 8.25 (SD 1.27) preoperatively to 2.85 (SD 1.31) at 1 year postoperatively in PS group ($p < 0.001$). The difference of VAS score between the two group was also significant ($p = 0.0160$). At one year postoperatively, the mean ODI score in CBT group was decreased from 68% ± 37% to 9% ± 10% and from 58% ± 15% to 23% ± 9% in the PS group. The ODI score at one year postoperatively was found to be significantly different between the two groups ($p = 0.0150$). In surgical morbidities there was no significant difference between the two groups in terms of operative time and radiation dose area product ($p = 0.0993$ and $p = 0.6913$ respectively). However, in terms of mean blood loss and length of hospital stay there was significant difference between the two groups ($p = 0.0392$ and 0.0413 respectively). There were 3 cases of screw malpositioning in both groups without neurological complication and one case with superficial wound infection which is treated with antibiotic therapy

4.6. Sakura, Miwa, Kuroda *et al.* (2018) [42]

Between the November 2011 and September 2013, 22 patients were undergone 2-level PLIF with CBT screw fixation for 2 level DS (CBT group) and between august 2009 and October 2011, 20 patients were undergone 2-level PLIF with traditional PS fixation for 2-level DS (PS group). The mean operative time and the blood loss during surgery were 192 ± 30 minutes and 495 ± 386 ml in CBT group and 218 ± 49 minutes and 612 ± 424 ml in PS group respectively ($p < 0.05$ and $p > 0.05$ respectively). There was significant improvement on mean JOA score from 12.3 points preoperative to 21.1 points (mean recovery rate 54.4%) on final follow up in CBT group compared to 12.8 points pre-operative to 20.4 points (mean recovery rate 51.8%) on final follow up on PS group ($p > 0.05$). The solid fusion was found on 40 off the 44 segments (fusion rate 90.9%) in CBT group and 38 off the 40 segments (fusion rate 95.0%) in the PS group ($p > 0.05$). Two patients in the CBT group (9.1%) and 4 patients in the PS group (20.0%) developed ASD. Perioperative complication (such as dural laceration, misplacement of screw, symptomatic hematoma and delayed wound healing) was seen on 2 patients (9.1%) in CBT group and 3 patients (15.0%) in the PS group.

5. Discussion

Divergent, CBT screw technique has been regarded as novel lumbar PS fixation method [15]. The insertion torque during CBT screwing in vivo is 1.71 times higher than that of traditional pedicle screwing as reported by Matsukawa *et al.* [16]. CBT is known to have several advantages over the limitation of traditional pedicle screw fixation method. CBT has caudomedial starting point which leads to the less invasive posterior lumbar fusion surgery by reducing the length of incision and dissection of parspinal muscle. Moreover using the caudomedial starting point and caudocephalad and mediolateral directed path of screw also prevent superior facet joint violation and dural injury [14] [21] [29] [43]. In terms of pullout strength and stability biomechanical studies has demonstrated that the CS has equivalent or superior property compared to the PS [18] [19] [20]. Several short term clinical studies have been conducted which compare the clinical outcomes between the CBT and PS.

One of the important concern for the PS is the risk of superior articulating facet violation during the screw placement and another is the need of long incison length and muscle dissection due to very lateral to midline entry of PS, at the lateral wall of pedicle [7] [44] [45] [46]. Previous studies have shown that superior facet joint violation during PS placement is 4% to 24% in the open surgery and 11% to 100% in percutaneous surgery [7] [46]. Lee *et al.* and Marengo *et al.* also reported that the facet joint violation was more in the PS group than in the CBT group [25] [41].

Fusion rate is considered as one of the most important factors in the evaluation of the safety and efficacy of CBT in PLIF surgery and influence the postoperative clinical outcomes and patient satisfaction. Most of the studies showed similar fusion rate in both the groups at 6 month and the final follow up. However, Sakura *et al.* have reported the lower fusion rate in CBT group than in the PS group although the difference was not significant ($p > 0.05$). They used unusual entry point for the CBT to minimize the skin incision caudally and starting point was articular surface of the superior articular process which is the possible trajectory with some merit but has not been confirmed definitely regarding its strength and safety [28] [42]. Some recent paper has revealed that using CBT in lumbar fusion surgery may produce slightly lower fusion rates in comparison with PS but no significant difference between the rates [22] [29] [47] [48].

In terms of clinical outcome pain intensity was evaluated by using the VAS score. Hung, Weng *et al.* and Lee and Ahn saw decrease in back pain and radiating pain in both CBT and PS group and there was no significant difference between the group at final follow-up ($p > 0.05$) [39] [40]. Marengo *et al.* described there is significant decrease in back pain in both the group postoperatively but noted that PS group has significantly higher VAS pain score at discharge (5.55 vs. 4.7, $p = 0.0471$) and 1 year follow up (2.85 vs. 1.95, $p = 0.0160$) [41]. Lee, Son *et al.* have found that the VAS score for lower back pain at postoperative week one is significantly lower in the CBT group in comparison to the PS group. This may be due to the smaller incision size, decreased disruption of muscle attachment and soft tissue dissection in CBT group [25]. However, most of the literature has suggested that the CBT technique has similar decreased pain level in comparison to the traditional PS technique. Disability was evaluated by using the ODI score. Lee, Son *et al.,* lee and Ahn and Hung, Weng *et al.* reported that the mean ODI score had improved on both the groups postoperatively in comparison to the preoperative score but showed no significant difference between the two groups [25] [39] [40]. However, Marengo *et al.* described there was significant decrease in ODI score in both the group postoperatively but noted that PS group had significantly higher ODI score at discharge (40% ± 8% vs. 30% ± 22%, $p = 0.04$) and 1-year follow-up (23% ± 9% vs. 9% ± 10%, $p = 0.0150$). This may be due to small skin incision and less muscle dissection needed to gain the screws' entry point [41]. Sakura *et al.* (2016) and Hung, Weng *et al.* further evaluated the treatment of lower back pain by using JOA score. All of the studies reported that the JOA score had improved on both the groups postoperatively in comparison to the preoperative score but showed no significant difference between the two groups. The improvement of JOA score on both CBT and PS group indicate the better quality life in patient with the back pain [28] [39] [42].

Operative time is an important factor of evaluating the surgical technique as prolonged operative duration results in higher rate of intraoperative outcomes, postoperative complication and higher rate of infection. Most of the studies have shown that there is no significant difference between the two groups in terms of operative time. However, Sakura *et al.* and Lee *et al.* demonstrated the significant finding in that PS procedures were longer in duration than the PLIF performed via CBT ($p < 0.05$) [25] [28] [42].

Blood loss can be considered as the important factor in assessing the different technique due to its impact on postoperative mortality. Lee, Son *et al.* and Marengo *et al.* have shown that CBT group has less blood loss than PS group and has significant difference between the two groups ($p < 0.05$) [25] [41]. However, all the other studies has revealed that CBT group has less blood loss than the PS group but no significant difference between the two groups. Overall finding shows that there is less blood loss in CBT approach than the PS approach so might be helpful in choosing the surgical technique for lumbar fusion in the surgically high risk patient [28] [39] [40] [42]. All the studies have shown that there is no difference in the intraoperative complications (dural tear, misplacement of pedicle screw) between the two groups. However postoperative complication (wound and other problems) was lower in CBT group than PS group. Wound problem (infection or hematoma) may be due to the longer and wider dissection needed for PS fixation and other problems (implant migration, loss of reduction, ASD and osteolysis) could be due to facet joint violation due to PS fixation [25] [28] [40] [41] [42].

6. Conclusion

In summary, both the groups have similar clinical outcome based on pain intensity (VAS score), disability status (ODI score) and JOA score as well as radiological evaluated complication such as loosening of screw. In terms of fusion rate there was similar result between the two groups; however, some studies showed lower fusion rate in CBT group than in PS group but the difference was not statistically significant. Moreover, PLIF with CBT has additional advantages of less facet joint violation, less blood loss, less intraoperative muscle damage and perioperative pain. On the basis of these result this review suggests that CBT provides similar clinical outcomes compared to the PS in PLIF and can be considered as a reasonable alternative to PS in PLIF.

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Conflicts of Interest

None.

References

[1] Herkowitz, H.N., Garfin, S.R., Eismont, F.J., Bell, G.R. and Balderston, R.A. (2011) Rothman-Simeone: The Spine E-Book: Expert Consult. Vol. 1: Elsevier Health Sciences.

[2] White, A.H., Ray, C.D. and Rothman, R.H. (1987) Lumbar Spine Surgery: Techniques & Complications.

[3] Verlooy, J., De, K.S. and Selosse, P. (1993) Failure of a Modified Posterior Lumbar Interbody Fusion Technique to Produce Adequate Pain Relief in Isthmic Spondylolytic Grade 1 Spondylolisthesis Patients. A Prospective Study of 20 Patients. *Spine*, **18**, 1491-1495. https://doi.org/10.1097/00007632-199318110-00014

[4] Abbas, J., Hamoud, K., May, H., Peled, N., Sarig, R., Stein, D., Alperovitch-Najemson, D. and Hershkovitz, I. (2013) Socioeconomic and Physical Characteristics of Individuals with Degenerative Lumbar Spinal Stenosis. *Spine*, **38**, E554-E561. https://doi.org/10.1097/BRS.0b013e31828a2846

[5] Pannell, W.C., Savin, D.D., Scott, T.P., Wang, J.C. and Daubs, M.D. (2015) Trends in the Surgical Treatment of Lumbar Spine Disease in the United States. *The Spine Journal*, **15**, 1719-1727. https://doi.org/10.1016/j.spinee.2013.10.014

[6] Liu, X.-Y., Wang, Y.-P., Qiu, G.-X., Weng, X.-S. and Yu, B. (2014) Meta-Analysis of Circumferential Fusion versus Posterolateral Fusion in Lumbar Spondylolisthesis. *Clinical Spine Surgery*, **27**, E282-E293. https://doi.org/10.1097/BSD.0000000000000116

[7] Jones-Quaidoo, S.M., Djurasovic, M., Owens, R.K. and Carreon, L.Y. (2013) Superior Articulating Facet Violation: Percutaneous versus Open Techniques. *Journal of Neurosurgery*: *Spine*, **18**, 593-597. https://doi.org/10.3171/2013.3.SPINE12829

[8] Lee, G.W., Lee, S.-M., Ahn, M.-W., Kim, H.-J. and Yeom, J.S. (2014) Comparison of Posterolateral Lumbar Fusion and Posterior Lumbar Interbody Fusion for Patients Younger than 60 Years with Isthmic Spondylolisthesis. *Spine*, **39**, E1475-E1480. https://doi.org/10.1097/BRS.0000000000000596

[9] Lee, S.-M. and Lee, G.W. (2015) The Impact of Generalized Joint Laxity on the Clinical and Radiological Outcomes of Single-Level Posterior Lumbar Interbody

Fusion. *The Spine Journal*, **15**, 809-816. https://doi.org/10.1016/j.spinee.2014.12.013

[10] İnceoğlu, S., Montgomery Jr., W.H., Clair, S.S. and McLain, R.F. (2011) Pedicle Screw Insertion Angle and Pullout Strength: Comparison of 2 Proposed Strategies. *Journal of Neurosurgery: Spine*, **14**, 670-676. https://doi.org/10.3171/2010.11.SPINE09886

[11] Rantanen, J., Hurme, M., Falck, B., Alaranta, H., Nykvist, F., Lehto, M., Einola, S. and Kalimo, H. (1993) The Lumbar Multifidus Muscle Five Years after Surgery for a Lumbar Intervertebral Disc Herniation. *Spine*, **18**, 568-574. https://doi.org/10.1097/00007632-199304000-00008

[12] Okuda, S., Iwasaki, M., Miyauchi, A., Aono, H., Morita, M. and Yamamoto, T. (2004) Risk Factors for Adjacent Segment Degeneration after PLIF. *Spine*, **29**, 1535-1540. https://doi.org/10.1097/01.BRS.0000131417.93637.9D

[13] Lowery, G.L. and Kulkarni, S.S. (2000) Posterior Percutaneous Spine Instrumentation. *European Spine Journal*, **9**, S126-S130. https://doi.org/10.1007/PL00008318

[14] Song, T., Hsu, W.K. and Ye, T. (2014) Lumbar Pedicle Cortical Bone Trajectory Screw. *Chinese Medical Journal*, **127**, 3808-3813.

[15] Santoni, B., Hynes, R., McGilvray, K., Rodriguez-Canessa, G., Lyons, A., Henson, M., Womack, W. and Puttlitz, C. (2009) Cortical Bone Trajectory for Lumbar Pedicle Screws. *The Spine Journal*, **9**, 366-373. https://doi.org/10.1016/j.spinee.2008.07.008

[16] Matsukawa, K., Yato, Y., Kato, T., Imabayashi, H., Asazuma, T. and Nemoto, K. (2014) *In Vivo* Analysis of Insertional Torque during Pedicle Screwing Using Cortical Bone Trajectory Technique. *Spine*, **39**, E240-E245. https://doi.org/10.1097/BRS.0000000000000116

[17] Baluch, D.A., Patel, A.A., Lullo, B., Havey, R.M., Voronov, L.I., Nguyen, N.-L., Carandang, G., Ghanayem, A.J. and Patwardhan, A.G. (2014) Effect of Physiological Loads on Cortical and Traditional Pedicle Screw Fixation. *Spine*, **39**, E1297-E1302. https://doi.org/10.1097/BRS.0000000000000553

[18] Perez-Orribo, L., Kalb, S., Reyes, P.M., Chang, S.W. and Crawford, N.R. (2013) Biomechanics of Lumbar Cortical Screw-Rod Fixation versus Pedicle Screw-Rod Fixation with and without Interbody Support. *Spine*, **38**, 635-641. https://doi.org/10.1097/BRS.0b013e318279a95e

[19] Akpolat, Y.T., Inceoglu, S., Kinne, N., Hunt, D. and Cheng, W.K. (2016) Fatigue Performance of Cortical Bone Trajectory Screw Compared with Standard Trajectory Pedicle Screw. *Spine*, **41**, E335-E341. https://doi.org/10.1097/BRS.0000000000001233

[20] Sakaura, H., Miwa, T., Yamashita, T., Kuroda, Y. and Ohwada, T. (2016) Fixation Strength of Caudal Pedicle Screws after Posterior Lumbar Interbody Fusion with the Modified Cortical Bone Trajectory Screw Method. *Asian Spine Journal*, **10**, 639-645. https://doi.org/10.4184/asj.2016.10.4.639

[21] Chin, K.R., Pencle, F.J., Coombs, A.V., Elsharkawy, M., Packer, C.F., Hothem, E.A. and Seale, J.A. (2017) Clinical Outcomes with Midline Cortical Bone Trajectory Pedicle Screws versus Traditional Pedicle Screws in Moving Lumbar Fusions from Hospitals to Outpatient Surgery Centers. *Clinical Spine Surgery*, **30**, E791-E797.

[22] Chen, Y.-R., Deb, S., Pham, L. and Singh, H. (2016) Minimally Invasive Lumbar Pedicle Screw Fixation Using Cortical Bone Trajectory—A Prospective Cohort Study on Postoperative Pain Outcomes. *Cureus*, **8**, e714.

[23] Kasukawa, Y., Miyakoshi, N., Hongo, M., Ishikawa, Y., Kudo, D. and Shimada, Y.

(2015) Short-Term Results of Transforaminal Lumbar Interbody Fusion Using Pedicle Screw with Cortical Bone Trajectory Compared with Conventional Trajectory. *Asian Spine Journal*, **9**, 440-448. https://doi.org/10.4184/asj.2015.9.3.440

[24] Ninomiya, K., Iwatsuki, K., Ohnishi, Y.-I. and Yoshimine, T. (2016) Radiological Evaluation of the Initial Fixation between Cortical Bone Trajectory and Conventional Pedicle Screw Technique for Lumbar Degenerative Spondylolisthesis. *Asian Spine Journal*, **10**, 251-257. https://doi.org/10.4184/asj.2016.10.2.251

[25] Lee, G.W., Son, J.-H., Ahn, M.-W., Kim, H.-J. and Yeom, J.S. (2015) The Comparison of Pedicle Screw and Cortical Screw in Posterior Lumbar Interbody Fusion: A Prospective Randomized Noninferiority Trial. *The Spine Journal*, **15**, 1519-1526. https://doi.org/10.1016/j.spinee.2015.02.038

[26] Orita, S., Inage, K., Kubota, G., Sainoh, T., Sato, J., Fujimoto, K., Shiga, Y., Nakamura, J., Matsuura, Y. and Eguchi, Y. (2016) One-Year Prospective Evaluation of the Technique of Percutaneous Cortical Bone Trajectory Spondylodesis in Comparison with Percutaneous Pedicle Screw Fixation: A Preliminary Report with Technical Note. *Journal of Neurological Surgery Part A*: *Central European Neurosurgery*, **77**, 531-537. https://doi.org/10.1055/s-0035-1566118

[27] Takenaka, S., Mukai, Y., Tateishi, K., Hosono, N., Fuji, T. and Kaito, T. (2017) Clinical Outcomes after Posterior Lumbar Interbody Fusion. *Clinical Spine Surgery*, **30**, E1411-E1418.

[28] Sakaura, H., Miwa, T., Yamashita, T., Kuroda, Y. and Ohwada, T. (2016) Posterior Lumbar Interbody Fusion with Cortical Bone Trajectory Screw Fixation versus Posterior Lumbar Interbody Fusion Using Traditional Pedicle Screw Fixation for Degenerative Lumbar Spondylolisthesis: A Comparative Study. *Journal of Neurosurgery*: *Spine*, **25**, 591-595. https://doi.org/10.3171/2016.3.SPINE151525

[29] Phan, K., Hogan, J., Maharaj, M. and Mobbs, R.J. (2015) Cortical Bone Trajectory for Lumbar Pedicle Screw Placement: A Review of Published Reports. *Orthopaedic Surgery*, **7**, 213-221. https://doi.org/10.1111/os.12185

[30] Ninomiya, K., Iwatsuki, K., Ohnishi, Y.-I., Ohkawa, T. and Yoshimine, T. (2016) Significance of the Pars Interarticularis in the Cortical Bone Trajectory Screw Technique: An *in Vivo* Insertional Torque Study. *Asian Spine Journal*, **10**, 901-906. https://doi.org/10.4184/asj.2016.10.5.901

[31] Gaines Jr., R.W. (2000) The Use of Pedicle-Screw Internal Fixation for the Operative Treatment of Spinal Disorders. *JBJS*, **82**, 1458-1476. https://doi.org/10.2106/00004623-200010000-00013

[32] Mobbs, R.J., Sivabalan, P. and Li, J. (2011) Technique, Challenges and Indications for Percutaneous Pedicle Screw Fixation. *Journal of Clinical Neuroscience*, **18**, 741-749. https://doi.org/10.1016/j.jocn.2010.09.019

[33] Matsukawa, K., Yato, Y., Kato, T., Imabayashi, H., Asazuma, T. and Nemoto, K. (2014) Cortical Bone Trajectory for Lumbosacral Fixation: Penetrating S-1 Endplate Screw Technique. *Journal of Neurosurgery*: *Spine*, **21**, 203-209. https://doi.org/10.3171/2014.3.SPINE13665

[34] Crichton, N. (2001) Visual Analogue Scale (VAS). *Journal of Clinical Nursing*, **10**, 706-706.

[35] Roland, M. and Fairbank, J. (2000) The Roland-Morris Disability Questionnaire and the Oswestry Disability Questionnaire. *Spine*, **25**, 3115-3124. https://doi.org/10.1097/00007632-200012150-00006

[36] Fairbank, J.C. and Pynsent, P.B. (2000) The Oswestry Disability Index. *Spine*, **25**, 2940-2953. https://doi.org/10.1097/00007632-200011150-00017

[37] Inoue, S. (1986) Assessment to Treatment for Low Back Pain. *The Journal of the Japanese Orthopaedic Association*, **60**, 391-394.

[38] Yone, K., Sakou, T., Kawauchi, Y., Yamaguchi, M. and Yanase, M. (1996) Indication of Fusion for Lumbar Spinal Stenosis in Elderly Patients and Its Significance. *Spine*, **21**, 242-248. https://doi.org/10.1097/00007632-199601150-00016

[39] Hung, C.-W., Wu, M.-F., Hong, R.-T., Weng, M.-J., Yu, G.-F. and Kao, C.-H. (2016) Comparison of Multifidus Muscle Atrophy after Posterior Lumbar Interbody Fusion with Conventional and Cortical Bone Trajectory. *Clinical Neurology and Neurosurgery*, **145**, 41-45. https://doi.org/10.1016/j.clineuro.2016.03.005

[40] Lee, G.W. and Ahn, M.-W. (2018) Comparative Study of Cortical Bone Trajectory-Pedicle Screw (Cortical Screw) versus Conventional Pedicle Screw in Single-Level Posterior Lumbar Interbody Fusion: A 2-Year Post Hoc Analysis from Prospectively Randomized Data. *World Neurosurgery*, **109**, e194-e202. https://doi.org/10.1016/j.wneu.2017.09.137

[41] Marengo, N., Ajello, M., Pecoraro, M.F., Pilloni, G., Vercelli, G., Cofano, F., Zenga, F., Ducati, A. and Garbossa, D. (2018) Cortical Bone Trajectory Screws in Posterior Lumbar Interbody Fusion: Minimally Invasive Surgery for Maximal Muscle Sparing—A Prospective Comparative Study with the Traditional Open Technique. *BioMed Research International*, **2018**, Article ID: 7424568.

[42] Sakaura, H., Miwa, T., Yamashita, T., Kuroda, Y. and Ohwada, T. (2018) Cortical Bone Trajectory Screw Fixation versus Traditional Pedicle Screw Fixation for 2-Level Posterior Lumbar Interbody Fusion: Comparison of Surgical Outcomes for 2-Level Degenerative Lumbar Spondylolisthesis. *Journal of Neurosurgery*: *Spine*, **28**, 57-62. https://doi.org/10.3171/2017.5.SPINE161154

[43] Matsukawa, K., Kato, T., Yato, Y., Sasao, H., Imabayashi, H., Hosogane, N., Asazuma, T. and Chiba, K. (2016) Incidence and Risk Factors of Adjacent Cranial Facet Joint Violation Following Pedicle Screw Insertion Using Cortical Bone Trajectory Technique. *Spine*, **41**, E851-E856. https://doi.org/10.1097/BRS.0000000000001459

[44] Athanasakopoulos, M., Mavrogenis, A.F., Triantafyllopoulos, G., Koufos, S. and Pneumaticos, S.G. (2013) Posterior Spinal Fusion Using Pedicle Screws. *Orthopedics*, **36**, e951-e957. https://doi.org/10.3928/01477447-20130624-28

[45] Oh, H.S., Kim, J.-S., Lee, S.-H., Liu, W.C. and Hong, S.-W. (2013) Comparison between the Accuracy of Percutaneous and Open Pedicle Screw Fixations in Lumbosacral Fusion. *The Spine Journal*, **13**, 1751-1757. https://doi.org/10.1016/j.spinee.2013.03.042

[46] Lau, D., Terman, S.W., Patel, R., La Marca, F. and Park, P. (2013) Incidence of and Risk Factors for Superior Facet Violation in Minimally Invasive versus Open Pedicle Screw Placement during Transforaminal Lumbar Interbody Fusion: A Comparative Analysis. *Journal of Neurosurgery*: *Spine*, **18**, 356-361. https://doi.org/10.3171/2013.1.SPINE12882

[47] Snyder, L.A., Martinez-del-Campo, E., Neal, M.T., Zaidi, H.A., Awad, A.-W., Bina, R., Ponce, F.A., Kaibara, T. and Chang, S.W. (2016) Lumbar Spinal Fixation with Cortical Bone Trajectory Pedicle Screws in 79 Patients with Degenerative Disease: Perioperative Outcomes and Complications. *World Neurosurgery*, **88**, 205-213. https://doi.org/10.1016/j.wneu.2015.12.065

[48] Mori, K., Nishizawa, K., Nakamura, A. and Imai, S. (2016) Short-Term Clinical Result of Cortical Bone Trajectory Technique for the Treatment of Degenerative Lumbar Spondylolisthesis with More than 1-Year Follow-Up. *Asian Spine Journal*, **10**, 238-244. https://doi.org/10.4184/asj.2016.10.2.238

Abbreviation

PLIF: posterior lumbar interbody fusion
CBT: cortical bone trajectory
PS: pedicle screw
CS: cortical screw
VAS: Visual Analog Scale
ODI: Oswestry Disability Index
JOA: Japanese Orthopedic Association