Incidence of Cranial Adjacent Segment Disease after Posterior Lumbar Interbody Fusion Using the Cortical Bone Trajectory Technique for the Treatment of Single-Level Degenerative Lumbar Spondylolisthesis; More than a 2-Year Follow-Up

Kanji Mori, Takafumi Yayama, Kazuya Nishizawa, Akira Nakamura, Hideki Saito, Masahiro Kitagawa and Shinji Imai

Department of Orthopaedic Surgery, Shiga University of Medical Science, Otsu, Japan

Abstract:

Introduction: Posterior lumbar interbody fusion (PLIF) is a widely used effective, safe, and established treatment for degenerative spinal disorders. Adjacent segment disease (ASD) is one of the serious concerns governing the clinical results following spinal fusion surgery. Cortical bone trajectory (CBT) is an alternative and less-invasive technique for lumbar pedicle screw placement. Its unique medial and caudal entry point has the potential to prevent an iatrogenic facet joint violence leading to the ASD; however, the incidence of ASD following PLIF using the CBT technique (CBT-PLIF) remains unknown.

Methods: Among patients surgically treated with CBT-PLIF in our institute, 52 consecutive patients (13 males, 39 females) with single-level degenerative lumbar spondylolisthesis (DLS) who were followed up for at least 24 months were exclusively enrolled. Their clinical and radiological features, including the incidence of radiographical and symptomatic ASD and significantly associated factor for the developing radiographical ASD, were retrospectively measured.

Results: In the present study, we could confirm significant neurological improvement and reduction of the spondylolisthesis with mean follow-up period of 43 months. Radiographical and symptomatic ASD was observed in 14 (27%) and 2 (3.8%) cases, respectively. We compared these two groups and found that the latest lumbar lordosis was significantly different between the two groups, but not in age, body mass index, and Japan Orthopaedic Association score. Two patients with symptomatic ASD required additional surgical treatment around 1 year following the initial surgery.

Conclusions: The present study, even though it is preliminary, revealed that CBT-PLIF can achieve a neurological improvement and an effective reduction of spondylolisthesis for the treatment of single-level DLS. The CBT technique is capable of reducing the incidence of ASD compared with the traditional technique; however, we must keep in mind that appropriate postoperative lumbar lordosis should be achieved. Larger, longer-term follow-up studies are required to elucidate the clinical output of CBT-PLIF.

Keywords:

Cortical bone trajectory, Adjacent segment disease, Degenerative lumbar spondylolisthesis, PLIF, Lumbar lordosis, Spinal fusion

Spine Surg Relat Res 2021; 5(2): 98-103

dx.doi.org/10.22603/ssrr.2020-0103

Introduction

Posterior lumbar interbody fusion (PLIF) is a widely used effective, safe, and established treatment for degenerative spinal disorders[1]. However, spinal fusion can accelerate degenerative changes in unfused adjacent segments. This spinal degenerative pathology is known as adjacent segment disease (ASD), which is one of the serious concerns governing the clinical results following spinal fusion surgery[1]. Accumulating studies have reported several factors associated with ASD, such as fusion length, fusion technique, fusion alignment, preoperative pathologies, adjacent segment decompression, iatrogenic destruction, and aging factor[1-3]. Several techniques for pedicle screw (PS) placement have been

Corresponding author: Kanji Mori, kanchi@belle.shiga-med.ac.jp

Received: May 25, 2020, Accepted: July 3, 2020, Advance Publication: August 31, 2020

developed, all of which have a latent risk of the adjacent cranial facet joint violation (FJV) during the placement of cranial PS. It has been reported that FJV is significantly associated with both radiographical and symptomatic ASD[2,3].

A cortical bone trajectory (CBT) is an alternative technique of lumbar PS placement advocated by Santoni et al. in 2009[4]. This novel technique facilitates maximum contact to the cortical bone through the pedicle to the vertebral body by following a unique caudal-to-cephalad trajectory in the sagittal plane and a medial-to-lateral directed trajectory in the transverse plane. Its unique screw entry point allows minimal soft tissue dissection, as compared with the traditional trajectory (TT) technique. This technique is therefore recognized as less invasive, with increased screw purchase[4-6]. We indicated this technique for the treatment of degenerative lumbar spondylolisthesis (DLS) and reported its favorable short-term result[7]. The unique medial and caudal entry point of the CBT technique might prevent an iatrogenic cranial FJV leading to cranial ASD; however, its incidence remains largely unknown. To the best of our knowledge, studies describing the incidence of ASD following PLIF using the CBT technique (CBT-PLIF) are limited. In the present report, although it is a preliminary result, we investigated the incidence of cranial ASD following CBT-PLIF. To eliminate various confounding factors associated with ASD, we exclusively evaluated the patients with single-level DLS treated with CBT-PLIF in this report.

Materials and Methods

Among patients surgically treated with CBT-PLIF in our institute, 52 consecutive patients (13 males, 39 females) with single-level DLS who were followed up for at least 24 months were exclusively enrolled. Their mean age at the time of surgery was 67 years old (range: 51-84 years old). The indications for surgical treatment were neurological compromise, intermittent claudication, and/or intractable lower leg pain with or without low-back pain following an adequate conservative treatment. This study was approved by the Institutional Review Board.

Evaluations

Basic and clinical data, including age at the time of surgery, sex, body mass index (BMI), and intra-/postoperative complications, such as pedicle fractures, dural tear, nerve injury, surgical site infection (SSI), and neurological deterioration, were retrospectively collected. To evaluate the neurological condition of each patient, the Japan Orthopaedic Association (JOA) score (range: 0-29)[8] was used. Preoperative, postoperative (1 month following surgery), and latest follow-up JOA scores were assessed.

Radiographical assessments were conducted as follows. The magnitude of spondylolisthesis was determined according to Meyerding's criteria[9]. Preoperative, postoperative, and latest follow-up percentage of slip (%slip) were measured. Lumbar lordosis (LL) at L1 to S1 and lordosis at fused segment (focal lordosis: FL) were determined with lateral lumbar radiographs using Cobb's method with the patient in a relaxed standing position[10]. Radiographical cranial ASD was defined as a reduction of more than 3 mm in disc height on a neutral lateral lumbar radiograph, an increase of more than 3 mm vertebral slip on lateral anterior-posterior bending lumbar radiograph, and dynamic intervertebral space angulation of more than 5° according to the previous report[1]. Symptomatic ASD was defined as a case that required additional surgical treatment due to cranial ASD, which was confirmed by magnetic resonance (MR) imaging.

Fusion status was evaluated 1 year following surgery by computed tomography (CT) or dynamic lumbar radiographs. A complete bony fusion was defined as a full trabecular continuity of the intervertebral disc space other than the cage at fused segment by CT or the absence of instability on lateral anterior-posterior bending lumbar radiographs.

Statistical analyses

Paired t-test, Wilcoxon signed-rank test, and chi-squared test were used for the statistical analyses. Results are expressed as mean±standard deviation. $P<0.05$ was considered statistically significant. The software application used for the analysis was SPSS version 22 (SPSS Inc., Chicago, IL).

Results

A total of 52 cases (13 males, 39 females) were included in this study. Their mean age at the time of surgery was 67 years old, and the mean follow-up period was 43 months. The levels of DLS were L3 in 10 cases and L4 in 42 cases. Thirty-four patients were of Grade I, and 18 were of Grade II, according to Meyerding's criteria[9]. Postoperatively, overt improvement of intermittent claudication was observed in all patients without neurological deterioration. The mean postoperative (25±2.5) and latest follow-up JOA scores (26±2.4) demonstrated significant recovery when compared with the mean preoperative JOA score (13±4.5) (Table 1).

The mean postoperative %slip (3.0±3.9) demonstrated significant improvement when compared with preoperative % slip (24±5.3). This significant reduction of slipped vertebrae was maintained until the latest follow-up (4.3±5.5). In addition, preoperative mean LL (29°±13°) and FL (6.0°±7.4°) were significantly restored to 40°±10° and 12°±5.4°, respectively, and they were maintained until the latest follow-up (LL: 32°±13°, FL: 9.4°±6.2°) (Table 1). Radiographical and symptomatic ASD was observed in 14 (27%) and 2 (3.8%) cases, respectively. We compared radiographical ASD positive and negative groups and found that the latest LL was significantly different between the two groups, but not in age, BMI, and JOA score (Table 2). In addition, no significant correlation was observed between the presence or absence of radiographical ASD and sex (p=0.72) or Meyerding's grade (p=0.58). The fusion rate at 1 year following surgery was 87%. In cases where complete fusion was achieved by CT, integration of the cage surface and endplate

Table 1. Neurological and Radiographical Evaluation of the Patients.

	JOA score			%slip (%)			LL (°)			FL (°)		
	Pre-op	Post-op	Latest FU	Pre-op	Post-op	Latest FU	Pre-op	Post-op	Latest FU	Pre-op	Post-op	Latest FU
Mean	13	25	26	24	3.0	4.3	29	40	32	6.0	12	9.4
SD	4.5	2.5	2.4	5.3	3.9	5.5	13	10	13	7.4	5.4	6.2
p-value	-	<0.001	<0.001	-	<0.001	<0.001	-	<0.001	0.05	-	<0.001	<0.001

JOA: Japan Orthopaedic Association, LL: lumbar lordosis, FL: focal lordosis at the fused segment, SD: standard deviation, Pre-op: preoperative; Post-op: postoperative; FU: follow-up, %slip: percentage of slip.

Table 2. Comparison between Patients with or without Radiographical Adjacent Segment Disease.

	R-ASD (+) (n=14)	R-ASD (−) (n=38)	*p*-value
Age	69±11	66±6.8	0.36
BMI (kg/m^2)	25±3.3	25±3.7	0.82
Pre-JOA score	13±5.2	14±4.2	0.62
Post-JOA score	25±2.4	26±2.6	0.58
Latest JOA score	25±2.9	26±2.2	0.30
Pre-LL	29±13	29±13	0.94
Post-LL	39±8.6	41±11	0.48
Latest-LL	25±15	35±11	0.013
Pre-FL	7.1±8.4	5.6±7.1	0.56
Post-FL	12±5.9	12±5.3	0.71
Latest-FL	8.7±6.2	9.7±6.2	0.62
Pre-%slip	23±6.7	24±4.8	0.81
Post-%slip	4.3±5.5	2.6±3.0	0.28
Latest-%slip	6.1±8.1	3.7±4.2	0.29

R-ASD: radiographical adjacent segment disease, BMI: body mass index, JOA: Japan Orthopaedic Association, Pre-op: preoperative, Post-op: postoperative, LL: lumbar lordosis, FL: focal lordosis at the fused segment, %slip: percentage of slip. Data except for p-value are expressed as mean±standard deviation.

and trabecular continuity of the intervertebral disc space other than the cage were observed. Two patients with symptomatic ASD (51 and 62 years old male patients) required additional decompression surgery due to cranial lumbar canal stenosis and facet cyst formation around 1 year following the initial surgery. A 62-year-old male patient with L4 DLS was treated with CBT-PLIF. The JOA score significantly improved from 6 to 28, with marked reduction of the L4 slip (Fig. 1A, B). Approximately 1 year following surgery, he complained of recurrence of left lower leg pain. We confirmed the loss of FL at unfused adjacent level (L3/4) (Fig. 1C). In addition, MR imaging revealed a lumbar canal stenosis not observed on MRI before the initial surgery as well as a facet cyst formation with facet effusion at the cranial unfused adjacent level (Fig. 2A-E). Additional decompression surgery resulted in the improvement of his symptom, and he did not require further surgery.

SSI was observed in one case that completely recovered because of one-time debridement and antibiotics therapy without implant removal. No other complication was observed.

Discussion

The present study, even though it is preliminary, revealed that CBT-PLIF can achieve neurological improvement and effective reduction of spondylolisthesis for the treatment of single-level DLS.

ASD is one of the serious concerns following spinal fusion surgery[1]. Previous reports have described the incidence of radiographical and symptomatic ASD with obviously different values; the incidence of radiographical and symptomatic ASD has been reported as 19%-84%[1,11-13] and 0%-24%[1,11-13], respectively. It is believed that the difference between the definitions of ASD and that between the follow-up periods of the reports were the likely cause. It is therefore difficult to compare the ASD rate of one study with those of others; however, the ASD rate of the present study was relatively low.

Reports concerning ASD following CBT-PLIF are scarce, because the CBT technique is a recently advocated procedure. Sakaura et al. reported that the incidence of symptomatic ASD in 95 consecutive patients with single-level DLS treated with CBT-PLIF was 3.2%[14]. More recently, they conducted a retrospective study on patients who had undergone

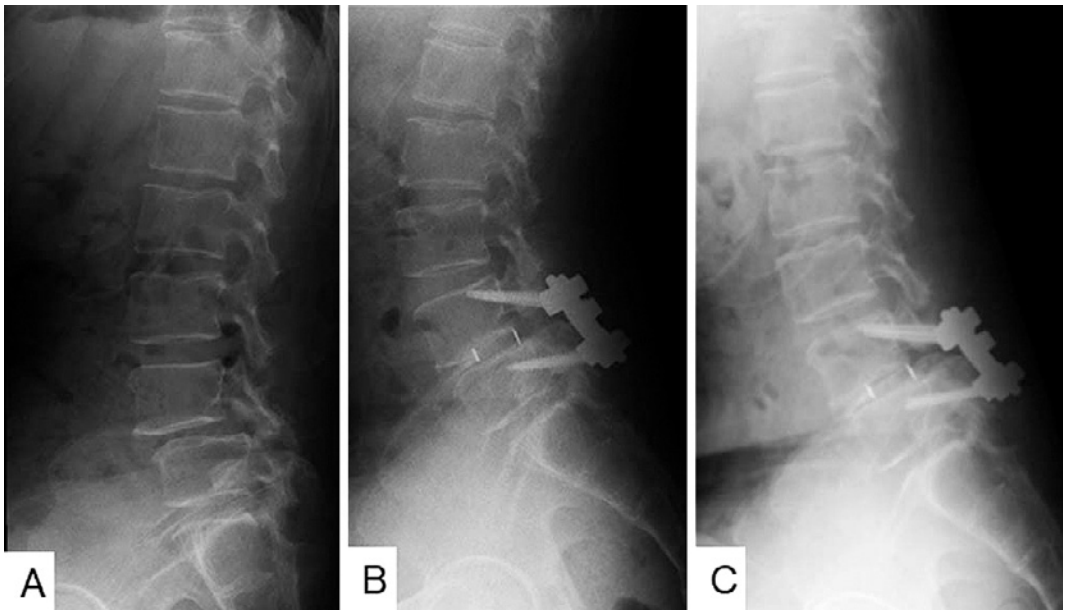

Figure 1. A 62-year-old male patient with symptomatic adjacent segment disease. Standard lateral lumbar radiograph before the initial surgery (A), after the initial surgery (B), and before the second surgery (C).

single-level CBT-PLIF or single-level TT-PLIF for DLS and with at least 3 years of postoperative follow-up[15]. They reported that the incidence of cranial radiographical ASD in the CBT group (12.7%) was significantly lower than that of the TT group (41.6%) ($p<0.0001$)[15]. For symptomatic ASD, however, no significant difference was observed between the CBT group (1.0%) and TT group (3.9%)[15]. The authors concluded that distinctive cranial CBT screw placement contributed to the lower incidence of radiographical ASD in the CBT group by preventing an iatrogenic cranial FJV leading to ASD. Matsukawa et al.[16] investigated FJV by CBT technique using postoperative CT, according to the classification of FJV advocated by Seo et al.[17]: grade 0: no violation; grade 1: screw or rod in contact with the facet joint, but did not enter the articular facet joint; and grade 2: screw or rod invaded the facet joint. Fig. 3 presents FJV by screw shaft in our series (Fig. 3). Matsukawa et al. reported that the incidence of FJV by CBT (11.8%) was lower than that of TT (15%-100%) and the independent factors significantly affecting FJV in the CBT technique were age>70 years, vertebral slip>10%, and adjacent facet joint degeneration (Pathria grade 2 or 3)[16]. CBT has the potential to reduce ASD by preventing FJV. The reason why our incidence of cranial ASD was higher than that of Sakaura et al.[15] remains unknown; however, it is possible that the proportion of ASD was high due to the small total number of cases. Other likely explanations include differences in the cases' conditions, such as the degree of facet degeneration and the precise surgical procedures. Further study with longer follow-up period in more cases is required to disclose that.

Several risk factors associated with the development of ASD were described previously. A recent systematic review reported that the risk factors of ASD following lumbar fusion surgery were age (≥60 years), genetic factors, high BMI, preexisting adjacent segment degeneration, laminectomy at the adjacent level of fusion, excessive distraction of the fusion level, insufficient LL, multilevel fixation, floating fusion (multilevel fixation with the lower end vertebra of L5), coronal wedging of L5-S disc, posterior tilting of the pelvis, and osteoporosis[18]. In the present study, consistent with previous reports, the latest LL was significantly associated with the radiographical ASD. Moreover, in the CBT technique, it is suggested that maintaining an appropriate LL is important to prevent ASD, as in the TT technique. The participants of the present study have exclusively single-level DLS, so it is difficult to voluntarily control the alignment of the total lumbar spine by single-level PLIF. However, we, spine surgeons, must keep in mind to achieve sufficient FL in performing lumbar spinal fusion. Indeed, biomechanical experiments revealed that local hypolordosis at the fused segment following lumbar fusion can enhance non-physiological load at the adjacent segment and promote its degeneration[19,20].

The limitations of the present study are the short follow-up period (minimum 24 months, mean 43 months); the limited number of cases without control arm; the definition of radiographical ASD in asymptomatic cases, which is only standard radiograph; and the lack of precise assessment of FJV. Another limitation is that the optimal postoperative lumbar sagittal alignment has not been set. Okuda et al. reported that the incidence of radiographical ASD increased with the follow-up period regardless of symptoms, reaching 75% 10 years following surgery[1]. The postoperative follow-up period of the present study is not sufficient to conclude the incidence of ASD; one cannot know the middle- and long-term results of the CBT-PLIF because the CBT technique is a newly advocated procedure. Larger, longer-term follow-up studies are required to elucidate the clinical output

Figure 2. Magnetic resonance imaging performed before the initial surgery (A–C) and the second surgery (D, E). The latter shows lumbar canal stenosis not observed on MRI before the initial surgery and facet cyst with facet effusion at the unfused adjacent level (D, E).

of the CBT technique.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: Approval number: 26-233. Approved by Shiga University of Medical Science

Author Contributions: Kanji Mori wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

Figure 3. Facet joint violence by screw shaft revealed by postoperative computed tomography.

Informed Consent: Informed consent was obtained by all participants in this study.

References

1. Okuda S, Nagamoto Y, Matsumoto T, et al. Adjacent segment disease after single segment posterior lumbar interbody fusion for degenerative spondylolisthesis: minimum 10 years follow-up. Spine (Phila Pa 1976). 2018;43(23):E1384-8.
2. Park P, Garton HJ, Gala VC, et al. Adjacent segment disease after lumbar or lumbosacral fusion: review of the literature. Spine. 2004;29(17):1938-44.
3. Babu R, Park JG, Mehta AI, et al. Comparison of superior-level facet joint violations during open and percutaneous pedicle screw placement. Neurosurgery. 2012;71(5):962-70.
4. Santoni BG, Hynes RA, McGilvray KC, et al. Cortical bone trajectory for lumbar pedicle screws. Spine J. 2009;9(5):366-73.
5. Matsukawa K, Yato Y, Nemoto O, et al. Morphometric measurement of cortical bone trajectory for lumbar pedicle screw insertion using computed tomography. J Spinal Disord Tech. 2013;26(6):E 248-53.
6. Matsukawa K, Yato Y, Kato T, et al. In vivo analysis of insertional torque during pedicle screwing using cortical bone trajectory technique. Spine (Phila Pa 1976). 2014;39(4):E240-5.
7. Mori K, Nishizawa K, Nakamura A, et al. 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 J. 2016;10(2):238-44.
8. Inoue S, Izumida S. Assessment of treatment for low back pain: Japanese Orthopaedic Association. J Jpn Orthop Ass. 1986;60: 391-4.
9. Meyerding HW. Spondylolisthesis. Surg Gynecol Obstet. 1932;54: 371-8.
10. Cobb J. Outline for the study of scoliosis. In: Edwards JW, editor. Michigan: Ann Arvor; 1948. Instruction course lectures. The

American Academy of Orthopedic Surgeons; p. 261-75.
11. Kim KH, Lee SH, Shim CS, et al. Adjacent segment disease after interbody fusion and pedicle screw fixations for isolated L4-L5 spondylolisthesis: a minimum five-year follow-up. Spine (Phila Pa 1976). 2010;35(6):625-34.
12. Nakai S, Yoshizawa H, Kobayashi S. Long-term follow-up study of posterior lumbar interbody fusion. J Spinal Disord. 1999;12(4): 293-9.
13. Nakashima H, Kawakami N, Tsuji T, et al. Adjacent segment disease after posterior lumbar interbody fusion: based on cases with a minimum of 10 years of follow-up. Spine (Phila Pa 1976). 2015; 40(14):E831-41.
14. Sakaura H, Miwa T, Yamashita T, et al. 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. J Neurosurg Spine. 2016;25(5):591-5.
15. Sakaura H, Ikegami D, Fujimori T, et al. Early cephalad adjacent segment degeneration after posterior lumbar interbody fusion: a comparative study between cortical bone trajectory screw fixation and traditional trajectory screw fixation. J Neurosurg Spine. 2019; 32(2):155-9.
16. Matsukawa K, Kato T, Yato Y, et al. Incidence and risk factors of adjacent cranial facet joint violation following pedicle screw insertion using cortical bone trajectory technique. Spine (Phila Pa 1976). 2016;41(14):E851-6.
17. Yson SC, Sembrano JN, Sanders PC, et al. Comparison of cranial facet joint violation rates between open and percutaneous pedicle screw placement using intraoperative 3-D CT (O-arm) computer navigation. Spine (Phila Pa 1976). 2013;38(4):E251-8.
18. Hashimoto K, Aizawa T, Kanno H, et al. Adjacent segment degeneration after fusion spinal surgery-a systematic review. Int Orthop. 2019;43(4):987-93.
19. Akamaru T, Kawahara N, Tim Yoon S, et al. Adjacent segment motion after a simulated lumbar fusion in different sagittal alignments: a biomechanical analysis. Spine (Phila Pa 1976). 2003;28 (14):1560-6.
20. Umehara S, Zindrick MR, Patwardhan AG, et al. The biomechanical effect of postoperative hypolordosis in instrumented lumbar fusion on instrumented and adjacent spinal segments. Spine (Phila Pa 1976). 2000;25(13):1617-24.