

Transforaminal Lumbar Interbody Fusion (TLIF) Using Pedicle Screws with Mobility

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Abstract

We believed that the delivery of a moderate compression force to bone grafts in transforaminal lumbar interbody fusion (TLIF) was better for bony union and performed the TLIF using a pedicle screw with mobility. Using the Segmental Spinal Correction System for TLIF, we investigated 13 patients with a minimum postoperative follow-up of 1 year. A good bony union was observed and clinical results included an improvement rate of 76.8%. Recent spinal instruments are made from more rigid and break-resistant materials. Bony union is less likely to be achieved in TLIF unless segmental subsidence is tolerated to some extent. The use of pedicle screws with mobility may enhance bony union.

Background: TLIF using a rigid pedicle screw has become the gold standard in spinal fusion. However, do stronger instruments have advantages for bony union? Bone grafts in TLIF once undergo necrosis and the volume decreases over time. If the disc height does not decrease accordingly, it will create some space between the grafted bone and both upper and lower vertebral bodies, which is disadvantageous for bony union. Thus, we considered that a pedicle screw with mobility would provide moderate compression force to the bone grafts in TLIF and would be better for bony union. The Segmental Spinal Correction System (SSCS) was used for TLIF in this study.

Results: We investigated the clinical results of this method in 13 patients (6 male and 7 female, 56 to 79 y/o) with a minimum 1-year follow-up. The mean JOA score improved from 13.5 pre-OP to 25.4 post-OP. The mean improvement rate was 76.8%. Bony union was observed for all patients.

Conclusion: TLIF using a pedicle screw with mobility provides moderate compression force to the bone grafts in TLIF and bony union may be enhanced. This could be a new method in spinal fusion surgery.

Keywords: Transforaminal lumbar interbody fusion; Bony union; Mobility

Introduction

A Transforaminal lumbar interbody fusion (TLIF) using pedicle screw has become the gold standard for spinal fusion. Instruments have been modified to be more rigid and break-resistant. However, do stronger instruments have advantages for bony union? Bone grafts in TLIF once undergo necrosis and their volume decreases over time. If disc height does not decrease accordingly, it will create some space between the grafted bone and both upper and lower vertebral bodies, which is disadvantageous for bony union. We believe that pedicle screws with mobility would provide moderate compression forces to the bone grafts during TLIF, and are better for bony unions. The Segmental Spinal Correction System (SSCS), a system for posterior dynamic stabilization, was used in this study. This paper describes surgical outcomes in 13 patients with a minimum postoperative follow-up of 1 year.

Subjects and Methods

We do obtain informed consent from patients before surgery. This procedure is usually used as a hybrid method on two segments. We apply TLIF to severe instability or foraminal stenosis and apply non-fusion stabilization to adjacent segments that have mild instability. Since rigid fusion for two segments will increase the frequency of adjacent segment diseases, we apply non-fusion stabilization to adjacent segments of TLIF level in order to decrease the occurrence of adjacent segment diseases.

TLIF was performed as a routine procedure, using the SSCS as an instrument. This system has rigid rods but provides a unique structure, which allows micro-motion with the hinged screw head. The hinge enables movement in the sagittal plane approximately 20°, but is stable in the lateral coronal plane and the rotational direction. Thus, motion in the sagittal plane is allowed whereas lateroflexion, rotation, and translation movements are controlled [1-5]. This indicates

that compression force is applied to the grafted bone by moderately tolerating axial stress [6] (Figure 1).

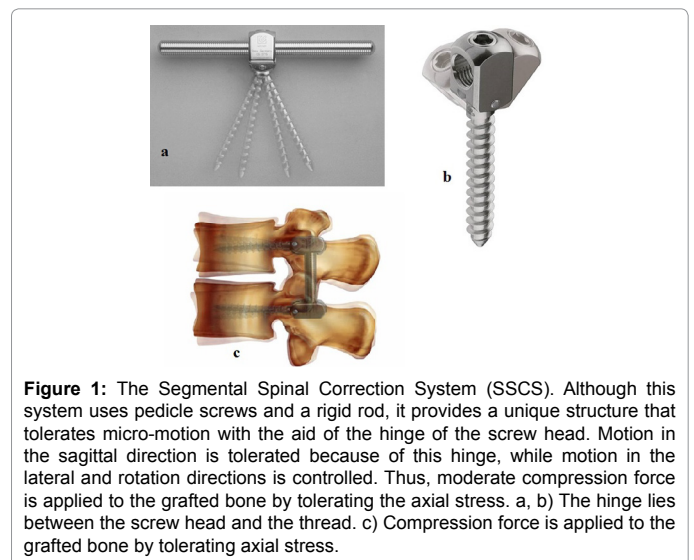


Figure 1: The Segmental Spinal Correction System (SSCS). Although this system uses pedicle screws and a rigid rod, it provides a unique structure that tolerates micro-motion with the aid of the hinge of the screw head. Motion in the sagittal direction is tolerated because of this hinge, while motion in the lateral and rotation directions is controlled. Thus, moderate compression force is applied to the grafted bone by tolerating the axial stress. a, b) The hinge lies between the screw head and the thread. c) Compression force is applied to the grafted bone by tolerating axial stress.

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Although it is also available for conventional TLIF, the main application of the SSCS is the hybrid procedure, which combines mono-segmental TLIF with cranial dynamic stabilization. The hybrid procedure consists of TLIF of a segment with instability or foraminal stenosis, and dynamic stabilization to the cranial segment with less instability. The SSCS was used in the hybrid procedure in 11 cases.

This study included 13 patients (6 male and 7 female) with a minimum postoperative follow-up of 1 year. The mean age at operation 65.8 years, ranged from 56 to 79 years. The study subjects consisted of 5 patients with lumbar degenerative spondylolisthesis, 2 with lumbar disc herniation, and 6 with adjacent segment disorder after posterior lumbar spinal fusion. Two cases were mono-segmental TLIF and the rest of the 11 cases were bi-segmental hybrid procedure. The segment fused with TLIF was L2/3, L3/4, and L4/5 in 2, 5, and 6 cases, respectively.

The mean follow-up period was 19.2 months, ranged from 14 to 27 months. Clinical outcomes, the condition of the bony union, anterior and posterior corner-to-corner distances for the segment that fused with the TLIF immediately after the operation and at the final follow-up, as well as the presence or absence of instrumentation failure, were reviewed in all cases.

Results

The mean Japanese Orthopaedic Association (JOA) score [7] (which correlates to Oswestry Disability Index and Roland-Morris Disability Questionnaire) JOA score (Table 1) improved from

I: Subjective symptom

Parameter	Finding	Points
Low Back Pain	None	3
	Occasional Mild Pain	2
	Frequent Mild	1
	Occasional Severe Pain	1
	Frequent Pain	0
	Continuous Pain	0
Leg pain and/or Tingling	None	3
	Occasional Slight Symptoms	2
	Frequent Slight Symptoms	1
	Occasional Severe Symptoms	1
	Frequent Severe Symptoms	0
	Continuous Severe Symptoms	0
Gait	Normal	3
	Able to walk > 500 meters although it results in pain tingling and/or muscle weakness	2
	Unable to walk > 500 meters owing to leg pain tingling and/or muscle weakness	1
	Unable to walk > 100 meters owing to leg pain tingling and/or muscle weakness	0

II: Clinical signs

Parameter	Finding	Points
Straight leg raising (includes a tight hamstring)	Normal (> 70°)	2
	30 to 70°	1
	< 30°	0
Sensory disturbance	None	2
	Slight disturbance (not subjective)	1
	Marked disturbance	0
Motor disturbance	Normal (Grade 5)	2
	Slight weakness (Grade 4)	1
	Marked weakness (Grades 0 to 3)	0

III: Restriction in activities

Parameter	Finding	Points
Turn over while lying	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Standing	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Washing	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Leaning forward	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Sitting about 1 hour	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Lifting or holding a heavy object	No restriction	2
	Moderate restriction	1
	Severe restriction	0
Walking	No restriction	2
	Moderate restriction	1
	Severe restriction	0

IV: Urinary bladder function

Parameter	Finding	Points
Urinary Bladder function	Normal	0
	Mild dysuria	-3
	Severe dysuria	-6

Table 1: Japanese Orthopedic Association (JOA) score. Parameters in the score: (1) Subjective symptoms (9 points): low back pain leg pain and/or tingling gait. (2) Clinical signs (6 points): straight-leg raising test sensory disturbance motor disturbance. (3) Restriction in activities (14 points): turn over while lying standing washing leaning forward sitting about 1 hour lifting or holding a heavy object walking. (4) Urinary bladder function (-6 points maximum).

preoperative 13.5 to postoperative 25.4 and the mean Hirabayashi recovery rate (Postoperative JOA score – Preoperative JOA score / full score – Preoperative JOA score ×100) was 76.8%. We checked bony union every 3 or 4 months after surgery with CT MPR (Multi Planar Reconstruction), bony union was assessed by the continuity of the bone graft in the cage and the pilot bone around it, with the upper and lower vertebral bodies. Bony union was achieved in 12 patients at 3 to 4 months after the operations and in 1 patient at 8 months after operation.

Immediately after the operation, the mean anterior and posterior corner-to-corner distances were 15.8 mm (range, 11.7 to 20.1 mm) and 9.4 mm (range, 6.1 to 13.1 mm), respectively. At the final follow-up, the mean anterior and posterior corner-to-corner distances were 11.9 mm (range, 7.5 to 14.4 mm) and 7.1 mm (range, 4.0 to 11.8 mm), respectively. The anterior and posterior corner-to-corner distances decreased by an average of 3.9 mm and 2.3 mm, respectively.

Instrumentation failure with screw breakage was observed in 1 out of 74 screws (1.4%), with no rod breakage. A radiolucent zone around screws was found in 1 patient who achieved bony union at 8th month. No symptoms were attributed to instrumentation failure.

Case Presentation

Case 1: 75 y/o male, L4 degenerative spondylolisthesis (Figure 2).

The patient presented with low back pain, numbness in both lower limbs, and intermittent claudication (40 meters) by pain. The MRI revealed severe stenosis at L4/5 and mild stenosis at L3/4. The

X-ray photograph revealed obvious spondylolisthesis at L4 and mild spondylolisthesis with antelexion at L3. When selecting the surgical procedures, there were split opinions which of the two options to perform; a combination of mono-segmental TLIF at L4/5 and decompression at L3/4, or bi-segmental fusion from L3 to L5. The selected procedure was the combination of TLIF at L4/5 and dynamic stabilization at L3/4. At 3 months after the operation, the CT MPR revealed good bony union and mild numbness in the lower limb was observed as the only residual clinical symptom.

Case 2: 70 y/o female, adjacent segment disorders after posterior lumbar spinal fusion (Figure 3).

The patient was in good condition after a TLIF operation at L4/5 for L4 degenerative spondylolisthesis, until pain in the right lower limb appeared 4 years after the operation. The MRI showed satisfactory decompression at L4/5 but adjacent segment disorder accompanied by disc herniation was observed at L3/4. Disc protrusion was also observed at L2/3. With the X-ray photograph, decrease in the disc height at L3/4 with posterior slippage was observed. For this patient, there were two options to take; mono-segmental or bi-segmental fusion. Since further extension of the fusion for adjacent segment disorder might lead to a vicious cycle, the screws at L4/5 were removed and combinations of TLIF at L3/4 and dynamic stabilization at L2/3 levels were performed. At 3 months after the operation, the CT scan showed good bony union at L3/4 and the preoperative symptoms resolved completely.

Case 3: 77 y/o female, adjacent segment disorders after posterior lumbar spinal fusion, and degenerative lumbar scoliosis (Figure 4).

The patient had been doing well after short fusion only at L4/5 for degenerative lumbar scoliosis. Low back pain and pain in the lower limbs appeared 6 years after the operation. The MRI showed satisfactory decompression at L4/5 but adjacent segment disorder at L3/4 was observed. Myelography revealed severe stenosis at L3/4 and

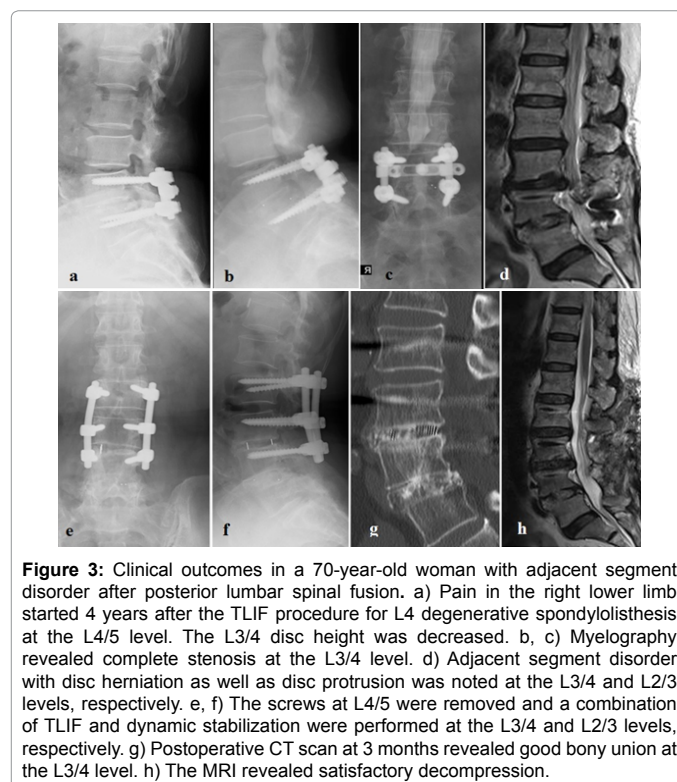


Figure 3: Clinical outcomes in a 70-year-old woman with adjacent segment disorder after posterior lumbar spinal fusion. a) Pain in the right lower limb started 4 years after the TLIF procedure for L4 degenerative spondylolisthesis at the L4/5 level. The L3/4 disc height was decreased. b, c) Myelography revealed complete stenosis at the L3/4 level. d) Adjacent segment disorder with disc herniation as well as disc protrusion was noted at the L3/4 and L2/3 levels, respectively. e, f) The screws at L4/5 were removed and a combination of TLIF and dynamic stabilization were performed at the L3/4 and L2/3 levels, respectively. g) Postoperative CT scan at 3 months revealed good bony union at the L3/4 level. h) The MRI revealed satisfactory decompression.

mild stenosis at L2 with posterior slippage. In this case, the degenerative scoliosis was corrected with rod rotation, the screws at L4/5 were removed and then a combination of TLIF at L3/4 and dynamic stabilization at L2/3 was performed. The CT scan showed good bony union 4 months after the operation. The patient was doing well at this time, with mild heaviness in the lumbar region as the only reported clinical symptom.

Discussion

Recent trends in the evolution of spinal instrumentation focus on rigid and break-resistant materials because of excessive concerns about breakage. However, the human spine is intrinsically flexible and it becomes osteoporotic with age. It is only natural that a gap manifests as radiolucency around screws or instrument breakage. Especially in TLIF, bony union is less likely to be achieved unless segmental subsidence is allowed to some extent. We believe that the use of pedicle screws with mobility in TLIF, instead of conventional rigid instruments, would provide a moderate compression force to the bone grafts and facilitate bony union. It is reasonable to address something flexible with something equally flexible. Although the number of cases and the follow-up period are limited, satisfactory bony union from an early stage and favorable clinical results have been obtained, in contrast to conventional TLIF.

This procedure is expected to result in a decrease in the local lordotic angle due to greater shortening in the anterior region. Limbus vertebra with defects in the anterior vertebral body or severe spondylolisthesis is not indications for this. However, as long as this procedure is used in cases of mild instability (those which meet posterior opening of the relevant segment of $\geq 5^\circ$, anterior slippage of ≥ 3 mm, or sagittalization of facet joints), loss of lordosis or progression to kyphosis has not been observed, possibly because of only slight local motion of 2° to 3° . In addition, attention should be paid to the insertion angle of screws. Theoretically, the more insertion angles are parallel, the more segmental motion are allowed but our experience shows that a medial

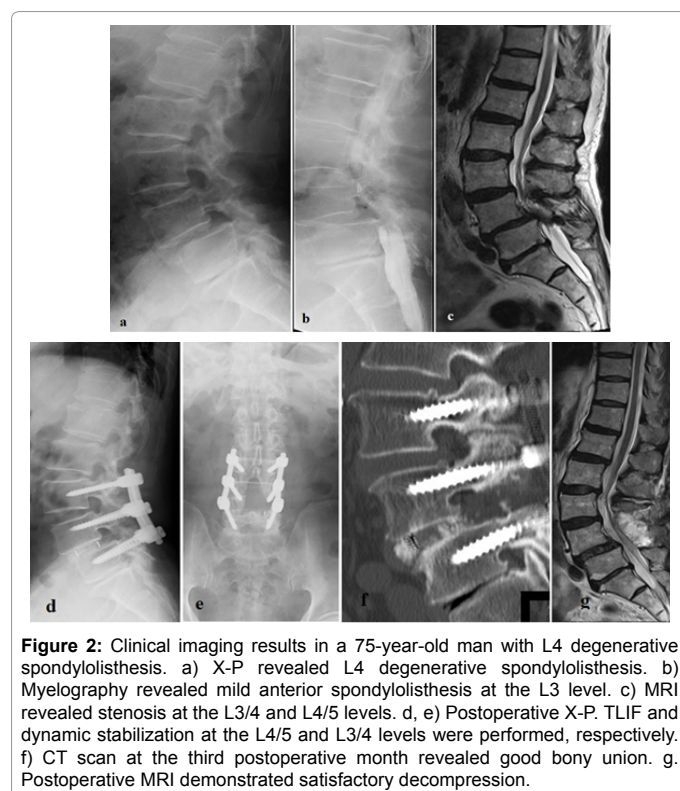


Figure 2: Clinical imaging results in a 75-year-old man with L4 degenerative spondylolisthesis. a) X-P revealed L4 degenerative spondylolisthesis. b) Myelography revealed mild anterior spondylolisthesis at the L3 level. c) MRI revealed stenosis at the L3/4 and L4/5 levels. d, e) Postoperative X-P. TLIF and dynamic stabilization at the L4/5 and L3/4 levels were performed, respectively. f) CT scan at the third postoperative month revealed good bony union. g. Postoperative MRI demonstrated satisfactory decompression.

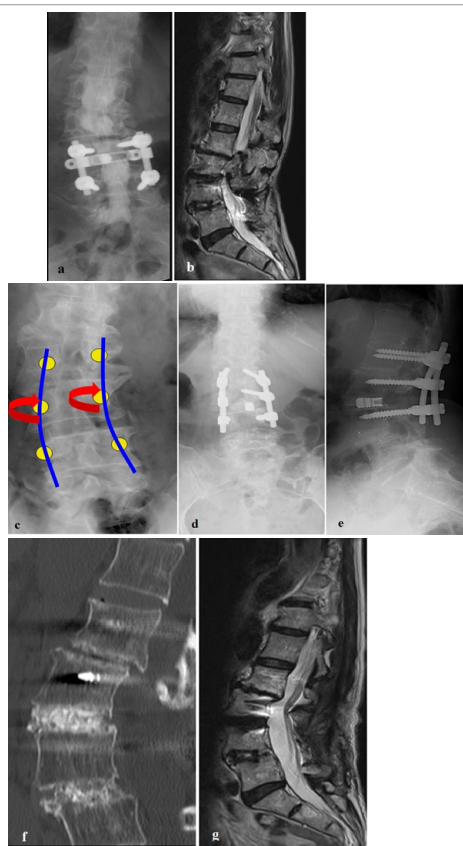


Figure 4: Clinical outcomes in a 77-year-old woman with adjacent segment disorder after posterior lumbar spinal fusion and degenerative lumbar scoliosis. a) The patient had been doing well after undergoing short fusion for degenerative lumbar scoliosis at the L4/5 level. Low back pain and pain in both lower limbs started 6 years after the operation. b) The MRI revealed the satisfactory maintenance of decompression at the L4/5 level. However, there was evidence for adjacent segment disorder at the L3/4 level. c) Due to degenerative scoliosis, correction of scoliosis with rod rotation was required. d, e) The screws were removed at the L4/5 level and a combination of TLIF and dynamic stabilization was performed at the L3/4 and L2/3 levels, respectively. f) Postoperative CT scans at 4 months revealed good bony union. g) Postoperative MRI showed satisfactory decompression.

insertion angle of up to 30° allows adequate segmental motion due to the allowance of the hinges. Since segmental subsidence does not occur in a parallel manner and the motion of anterior screws is greater in this system, more anterior placement of bone grafts in TLIF is more likely to produce compression force.

The largest advantage of this procedure lies in its hybrid procedure, in which both fusion and dynamic stabilization can be performed at the same time with a single device. This procedure is designed to facilitate bony union in TLIF by using pedicle screws with mobility, and to reduce adjacent segment disorder by allowing motion at the adjacent segments and smoothly making transition of rigidity with the same device.

It is premature to discuss adjacent segment disorder, based on this series of cases with the limited follow-up period, but we have already reported that dynamic stabilization with SSCS had less effect on adjacent segments. [1,2] With a follow-up of ≥ 5 years, when cases of dynamic stabilization with SSCS and TLIF with rigid instrumentation were compared, the rate of adjacent segment disorder resulted in reoperation was lower with the dynamic stabilization and was 7%

and 25%, respectively [8]. Since further extended fusion for adjacent segment disorder may lead to a vicious cycle [9], concomitant dynamic stabilization is considered valuable.

However, there are some limitations in this hybrid procedure using SSCS. One of the disadvantages of this system is that the screw head is closed and insertion of rod is relatively difficult. Two-level instrumentation can be the limitation for the instrumentation. Also, the motion of the stabilized segments does not last for good due to spontaneous facet joint union. Reviewing our minimum 5 years follow-up of non-fusion stabilization using SSCS, the occurrence of spontaneous facet joint union was 14% [8,10]. However, the occurrence of adjacent segment disorder was significantly less compared with rigid fusion. I think it is probably because the process of spontaneous fusion is very slow [11]. Lastly, it is not effective for the lower adjacent segment. For instance, even if hybrid procedure is applied to L3-5, it will not prevent adjacent segment disorder on L5/S1.

Conclusion

TLIF using pedicle screws with mobility provides moderate compression force to bone grafts and may enhance bony union. This could be a new method in spinal fusion surgery.

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