




Multi-segmental lumbar spinal stenosis treated with Dynesys stabilization versus lumbar fusion in elderly patients: a retrospective study with a minimum of 5 years' follow-up

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Abstract

Introduction Middle- and long-term outcomes of multi-segmental lumbar spinal stenosis treated with Dynesys stabilization (DS) have rarely been reported. Older age and multi-segmental degeneration may be positive factors in achieving satisfactory outcomes following DS. The present study aimed to compare the middle- and long-term outcomes of DS with lumbar fusion for treatment of multi-segmental lumbar spinal stenosis (ms-LSS) in elderly patients.

Materials and methods This study retrospectively analyzed patients with ms-LSS treated by DS or lumbar fusion from January 2011 to April 2013. Twenty-two patients were included in the Dynesys group, and 44 patients treated by lumbar fusion and rigid fixation were included in the fusion group. Clinical outcomes were assessed by VAS and ODI. Radiological outcomes were measured by range of motion (ROM) of stabilized segments and the proximal adjacent segment, intervertebral disc height (DH) and L1–S1 lumbar lordosis angle (LL). Modified Pfirrmann grade score was used to assess disc degeneration.

Outcomes The mean follow-up time of the Dynesys group and fusion group was 68.50 ± 6.40 and 70.14 ± 7.26 months, respectively. Baseline data were similar between the two groups. There were no significant differences between the two groups in terms of improvement of clinical outcomes (VAS and ODI). DS preserved a certain degree of ROM (3.74 ± 2.00) of surgical segments. ROM of proximal adjacent segment underwent an increase in both groups at the final follow-up. The DH of the surgical segments and proximal adjacent segment in both groups was significantly lower than that before surgery ($P=0.000$). LL of both groups improved ($P=0.000$), and there was no significant difference between the two groups. The modified Pfirrmann score of proximal adjacent segment of both groups increased at the final follow-up. The fusion group underwent a more significant increase ($P=0.000$), whereas the inter-group difference showed no significance ($P=0.090$).

Conclusion DS is a safe and effective surgical treatment of multi-segmental lumbar spinal stenosis in the elderly population. DS preserves a certain degree of mobility of surgical segments.

Keywords Lumbar spinal stenosis (LSS) · Multi-segmental · Dynesys · Fusion · Elderly

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Introduction

With the aging of society, there will be an increase in degenerative lumbar stenosis [1]. Radiologically diagnosed multi-segmental lumbar spinal stenosis (ms-LSS) occurs in more than 60% patients with LSS [2]. LSS is the most frequent indication for spine surgery in elderly patients [2–4]. Although the decision to perform a fusion or not remains controversial, many surgeons use lumbar fusion and rigid internal fixation to maintain spinal stability after decompression [5–8]. However, multi-segmental fusion surgery normally has more trauma, bleeding and longer operation time compared to those of non-fusion surgery [9]. In

addition, elderly patients often have comorbidities and tend to be less tolerant of major surgeries. Lumbar fusion restricts the surgical segments, resulting in increased load on adjacent segments and a compensatory increase in mobility. As the fusion segment increases, the risk of adjacent segment degeneration gradually increased [10]. When compared to short-segment fusion, long-segment fusion has more severe postoperative functional disability [11].

A variety of dynamic stabilization devices have been used in clinical practice to avoid the drawbacks of lumbar fusion and rigid fixation. The dynamic neutralization system (Dynesys) is a widely used posterior dynamic stabilization device. DS does not need the fusion of surgical segments and reduces both the surgical trauma and operation time. On the basis of stabilizing the lumbar segment, a certain degree of mobility of the surgical segment is preserved, improving the load conduction of the surgical segment [12]. Currently, studies have indicated that DS is a safe and effective surgical treatment of multi-segmental lumbar degenerative diseases in the short term [13–15]. However, middle- and long-term outcomes of multi-segmental lumbar spinal stenosis treated with DS have rarely been reported. Studies show that older age and multilevel degeneration may be positive factors for achieving satisfactory outcomes after DS [16, 17]. The present study aimed to observe middle- and long-term outcomes of multi-segmental DS in elderly patients. A further aim is to compare the results with the rigid instrumentation.

Methods

Patient population

In this retrospective study, patients with ms-LSS were admitted to our hospital from January 2011 to April 2013. Twenty-two patients who underwent DS were enrolled in the Dynesys group. Ms-LSS was diagnosed using a combination of clinical manifestations and signs identified on radiological images. Patients in the Dynesys group were matched to 44 patients of the fusion group on the basis of age, sex, surgical segments and operation date. The same length of instrumentation with the dynamic instrumentation or the rigid instrumentation was carried out in every case.

Inclusion criteria: (1) back and radicular symptoms with no relief at least 6 months after conservative treatment, (2) imaging confirmed multi-segmental lumbar spinal stenosis with or without a grade I degenerative spondylolisthesis, and (3) dynamic instability (proven on flexion–extension radiographs, $> 10^\circ$ of angulation or > 4 mm of slipping) or possible iatrogenic instability caused by decompression. Patients were educated on the treatment options with a thorough explanation of the risks and benefits. The final decision to perform DS or fusion was patient dependent. Patients with

grade II or higher spondylolisthesis, spondylolysis, lumbar infection, primary or metastatic tumour of the spine, metabolic bone disorders, spondylitis, previous lumbar surgery or severe osteoporosis were excluded.

The ethics committee of our hospital reviewed and approved this study.

Surgical technique

After general anesthesia, patients were transferred to the operating table in a prone position. After conventional disinfection and draping, a posterior midline incision was made. Then subcutaneous tissues, fascia, paraspinal muscles and lamina and screw entrance points of surgical segments were exposed.

For the Dynesys group, pedicle screws were placed into the surgical segments. Fluoroscopy was used to confirm the position of the screws. Complete decompression was performed according to the radiological imaging and physical examinations. Laminotomy was the standard technique to perform decompression with preservation of the facet joints. Polycarbonate urethane (PCU) spacers and polyethylene terephthalate (PET) cords were installed and locked.

Patients in the fusion group routinely underwent open TLIF. However, for some three-level and four-level fusion cases, a combination of post-lateral fusion and interbody fusion were applied to reduce operation time, decrease bleeding and control the expense of the device. The surgical procedure for fusion has been well described in other literature.

All wounds were copiously irrigated with saline before being closed. Negative pressure drainage tubes were routinely used for 1–2 days postoperatively.

Clinical and radiographic evaluations

In this study, the clinical and imaging indexes of pre-operation and final follow-up were compared. Clinical evaluation included the Oswestry Disability Index (ODI) and Pain Visual Analogue Scale (VAS, back and leg) score. Radiological evaluation included anterior–posterior and lateral and dynamic (flexion/extension) plain radiography and magnetic resonance imaging (MRI).

The range of motion (ROM) and intervertebral disc height (DH) of surgical and proximal adjacent segments and the L1–S1 lordosis angle (LL) were measured. The ROM of each segment was obtained by calculating the difference in the Cobb angles between the inferior surface of the upper vertebra and the superior surface of the lower vertebra using dynamic plain radiography. The average value of the posterior, middle and anterior intervertebral disc height was defined as DH. LL was formed by the Cobb angle between the superior endplates of L1 and S1. The modified Pfirrmann

score was used to assess disc degeneration [18]. Screw loosening was checked based on plain radiographs using the “double halo sign”.

Statistical analysis

Statistical analysis was performed using IBM SPSS 19.0. Independent sample *t* tests were used for inter-group comparisons. Paired sample *t* tests were used for comparison of preoperative and postoperative data within the group. Categorical data were compared by Chi square test. Measurement data are shown as the mean \pm standard deviation. Statistical significance was defined as $P < 0.05$.

Results

A total of 66 patients (age range 63–80 years) were enrolled in this study. The mean follow-up time of the Dynesys group and fusion group was 68.50 ± 6.40 and 70.14 ± 7.26 months, respectively ($P = 0.373$). There were no significant differences in age, sex, surgical segments or comorbidities between the two groups. The baseline information of the two groups is presented in Table 1. The ODI and VAS scores improved significantly in both groups ($P = 0.000$), and there was no significant inter-group difference at the final follow-up (Table 2).

The radiological outcomes are presented in Table 3. The postoperative ROM and modified Pfirrmann score of surgical segments in the fusion group were not collected and compared. The two groups were comparable in terms of preoperative radiological parameters. DS preserved a certain degree of ROM (3.74 ± 2.00) of surgical segments at the final follow-up, although there was a significant decrease compared to preoperative values. The ROM of the proximal adjacent segment of the fusion group was larger than that of

Table 1 Patients' baseline data

	Dynesys group	Fusion group	<i>P</i> value
Gender (male/female)	11/11	22/22	1.000
Age (years)	69.27 ± 4.92	69.41 ± 4.23	0.907
Follow-up (months)	68.50 ± 6.40	70.14 ± 7.26	0.373
Surgical levels			1.000
2	13	26	
3	7	14	
4	2	4	
Comorbidities			0.854
Diabetes	6	11	
Cardiovascular disorders	13	34	
Respiratory diseases	0	1	
Other	4	9	

Table 2 Clinical outcomes of patients

	Preoperative	Final follow-up	<i>P</i> value
VAS (back)			
Dynesys group	5.77 ± 1.31	1.77 ± 0.69	0.000
Fusion group	5.77 ± 1.38	1.73 ± 0.69	0.000
<i>P</i> value	1.000	0.802	
VAS (leg)			
Dynesys group	5.95 ± 1.00	1.68 ± 0.84	0.000
Fusion group	5.98 ± 1.39	1.70 ± 0.59	0.000
<i>P</i> value	0.946	0.899	
ODI (%)			
Dynesys group	68.82 ± 4.73	23.64 ± 4.17	0.000
Fusion group	69.16 ± 5.89	23.73 ± 6.66	0.000
<i>P</i> value	0.814	0.954	

VAS visual analog scale, ODI Oswestry Disability Index

Table 3 Radiological outcomes of surgical and proximal adjacent segment

	Preoperative	Final follow-up	<i>P</i> value
Surgical segments ROM (°)			
Dynesys group	5.90 ± 2.32	3.74 ± 2.00	0.000
Fusion group	5.94 ± 1.27		
<i>P</i> value	0.936		
Proximal adjacent segment ROM (°)			
Dynesys group	4.98 ± 2.51	5.37 ± 2.51	0.383
Fusion group	5.20 ± 1.74	7.86 ± 2.12	0.000
<i>P</i> value	0.714	0.000	
DH of surgical segments (mm)			
Dynesys group	9.32 ± 1.48	8.41 ± 1.57	0.000
Fusion group	9.33 ± 0.75	8.49 ± 0.72	0.000
<i>P</i> value	0.954	0.936	
DH of proximal adjacent segment (mm)			
Dynesys group	9.06 ± 1.52	8.33 ± 1.58	0.000
Fusion group	9.14 ± 1.05	8.36 ± 0.88	0.000
<i>P</i> value	0.809	0.842	
LL (°)			
Dynesys group	32.65 ± 8.27	38.51 ± 6.52	0.000
Fusion group	33.02 ± 8.89	37.63 ± 6.98	0.000
<i>P</i> value	0.872	0.624	
Modified Pfirrmann score of surgical segments			
Dynesys group	4.75 ± 0.77	4.88 ± 0.79	0.058
Fusion group	4.64 ± 0.62		
<i>P</i> value	0.548		
Modified Pfirrmann score of proximal adjacent segment			
Dynesys group	4.36 ± 0.73	4.45 ± 0.74	0.162
Fusion group	4.34 ± 0.78	4.82 ± 0.84	0.000
<i>P</i> value	0.909	0.090	

ROM: range of motion, DH: disc height, LL: L1–S1 lumbar lordosis angle

the Dynesys group at final follow-up ($P=0.000$). The DH values of the surgical segments and proximal adjacent segments in both groups were significantly lower than before surgery ($P=0.000$). LL of both groups improved at the final follow-up ($P=0.000$), and there was no significant difference between the two groups. The modified Pfirrmann score of the proximal adjacent segment of both groups increased at final follow-up. The fusion group underwent a more significant increase ($P=0.000$), whereas the inter-group difference was not significant ($P=0.090$). Typical cases from Dynesys group (Fig. 1) and the fusion group (Fig. 2) are presented below.

Complications occurred in 11 patients (50%) of the Dynesys group and 26 patients (59.1%) of the fusion group ($P=0.483$). The fusion group had more patients who experienced in-hospital complications (5 patients vs. 23 patients, $P=0.022$). For the Dynesys group, 2 patients (2 screws) underwent screw breakage and 6 patients (11 screws) underwent screw loosening. Eight patients (14 screws) were found to have screw loosening in the fusion group. These patients had no obvious symptoms, and thus, no patients needed further surgery. Other complications included cerebrovascular accident, pneumonia, atrial fibrillation, delirium, deep venous thrombosis, constipation, urinary tract infection,

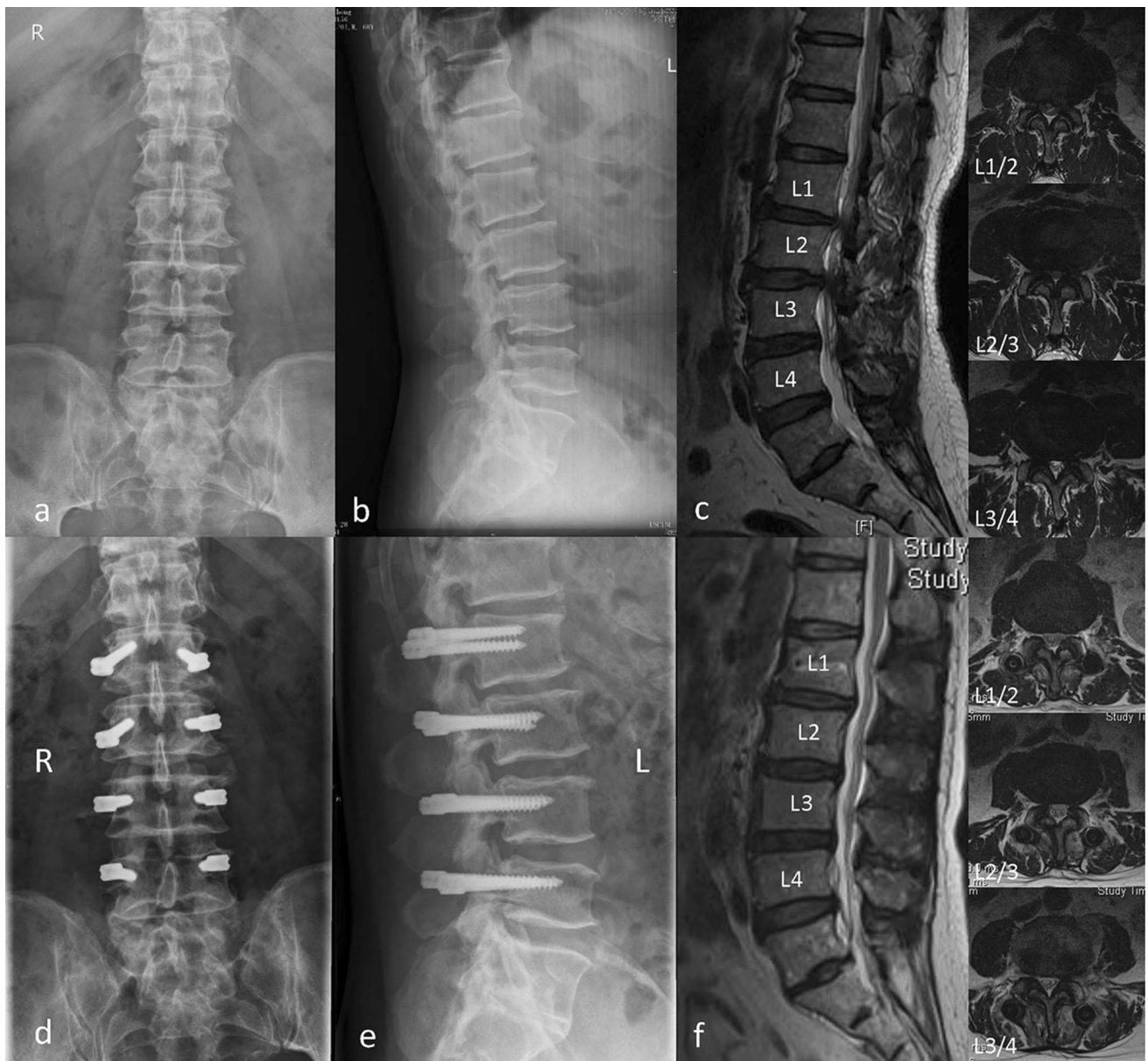


Fig. 1 A 69-year-old male patient underwent three-level DS (L1–L4). **a–c** Preoperative radiological imaging confirmed lumbar spinal stenosis. **d–f** Radiological imaging 5 years after surgery indicated that satisfactory decompression was achieved



Fig. 2 A 67-year-old female patient underwent three-level DS (L3–S1). **a–c** Preoperative radiological imaging confirmed lumbar spinal stenosis. **d–f** Radiological imaging 5 years after surgery indicated that satisfactory decompression was achieved

urinary retention, incision fat liquefaction, transfusion, readmission and deep infection. Summaries of the complications for both groups are presented in Table 4.

Discussion

The incidence of ms-LSS is increasing, but the optimal treatment of ms-LSS remains controversial. Multi-segmental decompression alone may result in spinal instability. Lumbar fusion is the most common procedure to maintain the stability of the spine, though it risks more blood loss and increased perioperative complications associated with the

fusion [7]. Studies have shown that the number of patients with LSS treated by decompression plus fusion remains large in many countries, such as Denmark [4], Sweden [4], Korea [5] and the US [8, 19]. However, fusion surgery often faces difficulties in treating ms-LSS, in terms of elderly patients' poor tolerance, bone-grafting materials, costs and surgical trauma. In addition, as the fusion segment increases, the adjacent segments are likely to bear more axial loading and degenerate faster, increasing the morbidity of adjacent segment disease [10]. One of the advantages of Dynesys is that the surgical procedure to implant it is less invasive and saves time, thus benefitting people who need earlier recovery, such as the elderly [20]. DS reduces the operation time

Table 4 Summary of complications for both groups

	Dynesys group	Fusion group	P value
In-hospital complications			
Cerebrovascular accident	0	1 (2.3)	0.667
Pneumonia	1 (4.5)	1 (2.3)	0.612
Atrial fibrillation	0	1 (2.3)	0.667
Delirium	0	2 (4.5)	0.441
Deep venous thrombosis	0	1 (2.3)	0.667
Constipation	1 (4.5)	2 (4.5)	1.000
Urinary tract infection	0	1 (2.3)	0.667
Urinary retention	1 (4.5)	1 (2.3)	0.612
Incision fat liquefaction	0	1 (2.3)	0.667
Transfusion	2 (9.1)	17 (38.6)	0.012
Total number of patients	5 (22.7)	23 (52.3)	0.022
Complications after discharge			
Readmission	0	1(2.3)	0.667
Deep infection	0	1(2.3)	0.667
Screw loosening	6 (27.3)	8 (18.2)	0.394
Screw loosening (screws level)	11 (7.1)	14 (4.5)	0.245
Screw breakage	2 (9.1)	0	0.108
Screw breakage (screws level)	2 (1.3)	0	0.111
Total number of patients	7 (31.8)	9 (20.5)	0.310

Values are presented as number (%)

and surgical bleeding because it does not require bone grafting and fusion [14]. A prospective cohort study has shown that DS was significantly superior to PLIF in intraoperative blood loss, hospital stay length and mobility preservation of the surgical segment [15]. DS is also cost effective compared to instrumented lumbar fusion for the treatment of lumbar degenerative diseases [15, 21].

Previously reported short-term clinical outcomes of multi-segmental DS are acceptable. Both two-level and three-level DS have achieved satisfactory outcomes, which were similar to those following PLIF [13, 14]. A systemic review has also indicated that DS seems as safe and effective as fusion [22]. However, long-term outcomes of multi-segmental DS have rarely been reported. Silvestre et al. [23] conducted a study of DS used to treat elderly patients with degenerative lumbar scoliosis. When compared to instrumented posterior fusion, DS was observed to be less invasive, require shorter hospital stay, result in less blood loss, and yield lower complication rates. Meanwhile, DS achieved stable and satisfactory long-term results with satisfying scoliosis curve reduction and lumbar lordosis. Our retrospective study showed that the improvement of clinical symptoms in the Dynesys group was similar to that in the fusion group. There was no significant difference in the clinical outcomes between the two groups. Although less positive outcomes of

DS than rigid stabilization were reported, a positive correlation was shown between older age and satisfactory outcomes with a 4-year follow-up [16].

It is still controversial whether DS can prevent ASD. Zhang et al. [24] compared DS to PLIF with an average follow-up of over 50 months. The increase in mobility of the proximal adjacent segment was significantly lower than that of the PLIF group. Our study shows that the Dynesys system can preserve a certain degree of mobility of the surgical segments while maintaining the stability of the spine. ROM of the proximal adjacent segment increased in both groups at the final follow-up, whereas the differences had significance only in the fusion group, which may support a conclusion that Dynesys can delay the degeneration of the adjacent segment. In a review of Dynesys stabilization, ASD developed in 7% of patients at a mean follow-up period of almost 3 years [25]. Although the reported incidence of ASD is highly variable, the overall incidence of ASD after DS appears to be lower than that of the reported incidences after lumbar fusion, which may be a manifestation of stress off-loading at the adjacent segment [25]. However, some studies have reported adverse outcomes. A study has shown that neither mono-segmental fusion nor mono-segmental DS altered proximal or distal adjacent level ROM [26]. Thus, Dynesys may have no advantages over instrumented fusion in terms of preventing ASD. St-Pierre et al. [17] reviewed 52 patients with a mean follow-up of 92 months. Dynesys was associated with a high rate of ASD. However, it was surprising that the authors found that radiological multilevel degeneration might be protective from clinical ASD. They hypothesized that multilevel degeneration may result in increased overall lumbar stiffness which can offset the influence of stabilization. No patients developed symptomatic adjacent segment disease in the present study.

In the present study, the intervertebral space of the operation segment decreased at the follow-up in both groups, while there was no difference between the two groups. However, in the studies conducted by Yu [14] and Fei [15], the intervertebral disc height of surgical segments in the DS group was higher than that of the fusion group after 3 years of follow-up, while the adjacent segments showed no significant difference. Fei et al. [15] concluded that the disc height in stabilized segments increased immediately after Dynesys implantation and then decreased during follow-up. As the degeneration of adjacent vertebrae is a long-term process, it may be more obvious in the long-term follow-up. Kim et al. [27] observed no decrease in disc height in either a mono-segmental stabilization group or a multi-segmental stabilization group with a mean follow-up of 31 ± 14 months. Dynesys uses PCU spacers and PET cords to limit extension and flexion, respectively. The length of the spacer and the pretension of the cord may vary based on the surgeon's decision. Differences in PET cord pretension result in a different stiffness of the device, which

may be part of the reason for the contrasting outcomes of the published study [20].

The most common complication of Dynesys is instrumentation failure. Wu et al. [28] reported that 4.7% of screws in 19.8% of patients loosened, although none of the patients needed revision surgery. They also indicated that elderly patients have higher rates of screw loosening. The rates of screw loosening and breakage are not uniform in the published literature. With a comprehensive literature review, Pham et al. [25] found that 11.7% (range 0–73.5%) of patients underwent screw loosening and 1.6% (range 0–8.1%) of patients had screw breakage during a mean follow-up period of 30.0 months. During our observation, six cases (27.3%) with screw loosening were identified based on plain radiographs by looking for a “double halo sign”. Two out of 22 patients (9.1%) in the present study developed screw breakage, which was higher than that reported by Pham et al. [25]. However, in terms of the number of screws implanted, our study had a comparable breakage rate with the published literature [2 out of 154 (1.3%) vs 4 out of 224 (1.8%)] [29]. In the present study, the cases with screw breakage or screw loosening showed no associated clinical symptoms, so the patients were followed up and checked regularly. It seems that DS had a higher incidence of pedicle screw loosening and a lower incidence of screw fractures. A possible reason is that Dynesys provides more flexibility than rigid constructs to reduce screw breakage, while the repeated internal stress may cause screw loosening. Apart from the hardware complications, more than one-third of patients (38.6%) in the fusion group received a transfusion ($P=0.012$) and more than half of patients (52.3%) experienced in-hospital complications ($P=0.022$). It is obvious that multi-segmental fusion was associated with greater surgical trauma to elderly patients. DS was shown to be safe to treat multi-segmental lumbar spinal stenosis in the elderly population during a hospital stay.

This study does have some limitations. The primary limitation is that the sample is small. The term “elderly patients” often refers to patients > 65 years old. We included three patients aged 63 years in Dynesys group because of a limited number of patients. Furthermore, the CT scan information was not available for all patients, and thus, the analysis of facet change in the Dynesys group and final confirmation of screw loosening and the fusion rate were difficult. Despite these limitations, we think that the information provided by this study is useful. A larger sample size and randomized controlled trials are needed to further determine the risks and benefits of Dynesys.

Conclusion

DS is a safe and effective surgical treatment of multi-segmental lumbar spinal stenosis in the elderly population. DS partially preserves the mobility of surgical segments, which may have the potential to delay degeneration of the surgically treated and adjacent segments.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Research involving human participants and/or animals For this type of study, formal consent is not required.

Informed consent All patients signed an informed consent before the surgery.

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