Dynesys dynamic stabilization–related facet arthrodesis

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OBJECTIVE Dynamic stabilization devices are designed to stabilize the spine while preserving some motion. However, there have been reports demonstrating limited motion at the instrumented level of the lumbar spine after Dynesys dynamic stabilization (DDS). The causes of this limited motion and its actual effects on outcomes after DDS remain elusive. In this study, the authors investigate the incidence of unintended facet arthrodesis after DDS and clinical outcomes.

METHODS This retrospective study included 80 consecutive patients with 1- or 2-level lumbar spinal stenosis who underwent laminectomy and DDS. All medical records, radiological data, and clinical evaluations were analyzed. Imaging studies included pre- and postoperative radiographs, MR images, and CT scans. Clinical outcomes were measured by a visual analog scale (VAS) for back and leg pain, the Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) scores. Furthermore, all patients had undergone postoperative CT for the detection of unintended arthrodesis of the facets at the indexed level, and range of motion was measured on standing dynamic radiographs.

RESULTS A total of 70 patients (87.5%) with a mean age of 64.0 years completed the minimum 24-month postoperative follow-up (mean duration 29.9 months). Unintended facet arthrodesis at the DDS instrumented level was demonstrated by CT in 38 (54.3%) of the 70 patients. The mean age of patients who had facet arthrodesis was 9.8 years greater than that of the patients who did not (68.3 vs 58.5 years, $p = 0.009$). There were no significant differences in clinical outcomes, including VAS back and leg pain, ODI, and JOA scores between patients with and without the unintended facet arthrodesis. Furthermore, those patients older than 60 years were more likely to have unintended facet arthrodesis (OR 12.42) and immobile spinal segments (OR 2.96) after DDS. Regardless of whether unintended facet arthrodesis was present or not, clinical evaluations demonstrated improvement in all patients (all $p < 0.05$).

CONCLUSIONS During the follow-up of more than 2 years, unintended facet arthrodesis was demonstrated in 54.3% of the patients who underwent 1- or 2-level DDS. Older patients (age > 60 years) were more likely to have unintended facet arthrodesis and subsequent immobile spinal segments. However, unintended facet arthrodesis did not affect the clinical outcomes during the study period. Further evaluations are needed to clarify the actual significance of this phenomenon.

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KEY WORDS lumbar spondylosis; Dynesys; dynamic stabilization; facet joints; arthrodesis

INSTRUMENTED spinal fusion surgery has been regarded as a standard treatment for patients with instability caused by severe lumbar spondylosis refractory to medical treatment. Various kinds of surgical approaches, including anterior, posterior, transforaminal, and lateral lumbar interbody fusion techniques, have demonstrated satisfactory fusion rates and promising outcomes in patients with degenerative spondylolisthesis, spinal stenosis

with instability, facet joint arthropathy, degenerative disc disease, or recurrent lumbar disc herniation.^{2,4,12,17,18,30,31} Although there are still issues with this fusion surgery, spinal arthrodesis has been a popular choice of strategy of surgical management for lumbar spondylosis.^{1,9,11,25,29}

In recent decades, there has been an emerging option of dynamic stabilization for lumbar spondylosis with preservation of spinal segmental motion. The Dynesys dynamic

ABBREVIATIONS ASD = adjacent-segment disease; DDS = Dynesys dynamic stabilization; JOA = Japanese Orthopaedic Association; ODI = Oswestry Disability Index; ROM = range of motion; VAS = visual analog scale.

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stabilization (DDS) system (Zimmer Spine), a spinal motion preservation system, consists of a pedicle screw-based stabilization device for the lumbar spine. The DDS was designed to unload the intervertebral disc and to shift axial loading to the elastic spacers of the system. Thus, recovery or rehydration of the degenerative discs might be expected in selected patients after DDS.⁷ Although several reports have demonstrated promising short- to midterm outcomes of DDS, the concerns with regard to nonfusion instrumentation are durability (e.g., screw loosening) and long-term effects.^{7,8,16,32} Nevertheless, substantial rates of screw loosening have been reported for DDS without adverse effects.^{7,8,16,26,27,32} Interestingly, several reports have demonstrated that only minimal segmental spinal motion was preserved in patients who underwent DDS.^{5,8,13,21,23,24,28} The actual cause of this limited motion remains elusive, and the effects of DDS on surrounding structures have not been fully addressed. Therefore, this study aimed to investigate the incidence of unintended facet arthrodesis, a phenomenon we noticed during the follow-up of these patients, and its clinical effects.

The purpose of the current study was to address an unintended result of DDS, facet arthrodesis, including its incidence rate, effects on segmental motion, and clinical outcomes. All patients were followed up for more than 2 years and evaluated with CT. This is the first report focused on unintended facet arthrodesis after DDS and its clinical impacts.

Methods

Inclusion/Exclusion of Patients

Consecutive cases at Taipei Veterans General Hospital involving patients with symptomatic lumbar spondylosis and spinal stenosis who underwent posterior decompression and dynamic stabilization between 2009 and 2011 were reviewed retrospectively. The clinical presentations of patients in the series included back pain, radicular pain, neurogenic claudication, or cauda equina syndrome. The pathologies included spinal stenosis with minimal spondylolisthesis, hypertrophy of ligamentum flavum, degenerative disc disease, and recurrent disc herniation. Patients were excluded if there was Meyerding Grade II spondylolisthesis, the presence of deformity, severe facet degeneration, or disc disease causing arthrodesis prior to surgery. Patients with less than 3° of segmental motion on dynamic lateral radiographs preoperatively had been designated for fusion surgery rather than DDS. Moreover, those patients who were lost to follow-up or did not complete evaluations at each time point were also excluded from analysis. This study was approved by the institutional ethics committee.

Surgical Technique

Under general anesthesia, the patient was placed on a Wilson frame (Steris) in a prone position with neutral lumbar lordosis and an adequate cushion. Midline skin and fascia incisions were made for decompression with total laminectomy. The narrow lateral recesses with hypertrophic ligamentum flavum were decompressed with a Kerrison rongeur and probed through to ensure that the nerve roots were free from compression. The facet joints

were preserved without violation, except that the medial one-third of each facet was resected in selected cases to achieve adequate decompression. Subsequently, bilateral fascial incisions were made for a direct approach through the Wiltse's plane to the junction of the transverse process and lateral facet joint. The Dynesys pedicle screws were then placed using standard techniques. Intraoperative fluoroscopy was then performed for confirmation. The facet joints were minimally exposed to ensure that the joint capsules were grossly intact without violation.

The diameter and length of the titanium alloy screws were estimated by both CT preoperatively and pedicle sound intraoperatively. Due to the self-tapping design of the Dynesys screws, we avoided removing and reinserting the screws. After placement of all screws, polycarbonate urethane spacers of appropriate lengths were assembled with polyethylene-terephthalate cords. The length of the elastic spacer was measured by the pedicle distraction gauge to ensure neutral lordosis in the indexed levels of the lumbar spine during extension. The tension cord inside the spacer aimed to provide controlled forward flexion movement. Theoretically, all patients were stabilized in a neutral to slightly lordotic position after DDS.

Clinical Evaluation

Our database was built prospectively with scheduled clinical and radiological examinations at each clinical visit. Standard pre- and postoperative questionnaires and clinical evaluations were aimed to be completed at 1.5, 3, 6, 12, and 24 months after surgery and with a 12-month interval thereafter. All the subjective questions were answered by patients with the assistance of nurses who were specially trained to obtain complete data for our prospective database. The objective assessment was performed by 2 study nurses under the supervision of the physicians.

Radiological Evaluation

All patients underwent preoperative standard and dynamic lateral radiography, MRI, and CT for evaluation. Postoperative follow-up included both plain and dynamic radiographs at 1.5, 3, 6, 12, and 24 months after surgery and every 12 months thereafter. Follow-up CT and MRI were undertaken at approximately 18 and 24 months after surgery.

Arthrodesis of the indexed facets after DDS was diagnosed by postoperative CT. Unintended facet arthrodesis was defined by obliteration of the joint space of the facet and formation of continuous cortical calcification between the superior and inferior articular processes on the postoperative CT scan. Moreover, lateral dynamic radiographs were measured for segmental range of motion (ROM) during flexion and extension. The difference of the Cobb angles of the superior and inferior endplates of the most cephalad and caudal segment between flexion and extension was calculated as the segmental ROM. Any ROM equal to or less than 3° during flexion and extension was defined as immobile. Theoretically, the unintended facet arthrodesis after DDS would correlate with immobility (e.g., loss of segmental ROM) in the indexed levels. All of the imaging studies were reviewed through the SmartIris

digital medical imaging system (Taiwan Electronic Data Processing Co.). Two radiologists and 2 neurosurgeons reviewed the images independently, and the coauthors made the final decision if there was any ambiguity among interpretations.

Statistical Analysis

All statistical analyses were performed using SPSS commercial software (SPSS Inc.). Independent t-tests and paired t-tests were used for continuous variables, and the Fisher exact test was applied for categorical data. The chi-square test was used for relation verification for 2 variables. A p value of 0.05 was considered to be statistically significant.

Results

Among the 80 consecutive patients who underwent DDS in this series, 70 patients (87.5%) completed postoperative clinical and radiological evaluations for more than 24 months. The mean follow-up duration was 29.9 ± 8.3 months. Their mean age was 64.0 ± 15.3 years at the time of surgery; 31 (44.3%) were female (Table 1). Thirty-one patients (44.3%) had degenerative spondylolisthesis.

Of the 70 patients analyzed, 27 (38.6%) underwent 1-level and 43 (61.4%) underwent 2-level DDS after decompression. A total of 366 screws were inserted and 226 facet joints were bridged in the series. The distribution of levels that underwent DDS varied from L-2 through S-1, as demonstrated in Fig. 1.

Facet Arthrodesis

Unintended facet arthrodesis was observed in 38 patients (54.3%) (Fig. 2) on the follow-up CT scans. The mean segmental ROM of these 38 patients whose facet joints were fused were $3.7^\circ \pm 3.3^\circ$. Furthermore, 27 of these patients (71.1%) were nearly immobile (having a ROM less than 3°) (Table 2) while the other 32 patients whose CT scans demonstrated no facet arthrodesis had a mean segmental ROM of $6.3^\circ \pm 2.6^\circ$, and only 3 of them (9.4%) were immobile (Fig. 3 and Table 2).

Patients who had facet arthrodesis had a higher rate of immobility after DDS in the stabilized lumbar segments compared with those who did not (71.1% vs 9.4%, $p <$

0.001). The mean age of patients with facet arthrodesis was significantly older than that of patients without facet arthrodesis (68.3 ± 13.8 years vs 58.5 ± 15.8 years, $p = 0.009$). The sex composition and the number of bridged levels were similar between patients with and without facet arthrodesis (Table 2). Table 3 shows the comparison of data between young and old patients.

There were 3 patients (4.3%) who had partial facet resection (medial one-third to decompress the lateral recess) scrutinized by comparison of the pre- and postoperative CT scans. Furthermore, there was no correlation between partial resection and rate of facet arthrodesis ($p = 0.435$) (Table 4).

The pre- and postoperative ROM of the lumbar spine was measured by lateral dynamic radiographs. The mean preoperative segmental ROM of all patients was $16.9^\circ \pm 7.2^\circ$ (minimum of 6°), which indicated that their lumbar spines were quite flexible. We then divided patients into 2 groups according to their flexibility: the larger ($> 16.9^\circ$) ROM group and the smaller ($\leq 16.9^\circ$) ROM group. There was no correlation between preoperative ROM and facet arthrodesis ($p = 0.278$) (Table 4).

Clinical Outcomes

Overall, the patients in the present series had significant improvement overall after surgery. The clinical outcomes, including visual analog scale (VAS) scores for back and leg pain and Oswestry Disability Index (ODI) and Japanese Orthopaedic Association (JOA) scores, were significantly improved at 3, 6, 12, and 24 months after the operation in comparison with preoperative scores (Table 2 and Fig. 4).

Unintended facet arthrodesis did not affect clinical outcomes. There were no differences between the group of patients with facet arthrodesis and those without in VAS scores for back and leg pain, ODI scores, and JOA scores before the operation ($p = 0.080, 0.258, 0.090$, and 0.654 , respectively) and after the operation ($p = 0.456, 0.267, 0.965$, and 0.608 , respectively). Overall, both groups showed significant improvement in VAS scores for back and leg pain as well as ODI and JOA scores (Table 2 and Fig. 4).

Comparison Between the Younger and Older Patients

Patients in the present series were further divided into 2 groups by age: a younger (≤ 60 years) and an older (> 60 years) group (Table 3). There were 23 patients in the younger group (mean age 49.5 ± 10.3 years). Six (26.1%) of these patients were found to have immobile spinal segments, and 4 patients (17.4%) had facet arthrodesis at postoperative follow-up. The older group consisted of 47 patients (mean age 72.4 ± 6.3 years). Twenty-four (51.1%) of the older patients were found to have immobile spinal segments, and 34 patients (72.3%) had facet arthrodesis at postoperative follow-up. Therefore, patients older than 60 years were more likely to have facet arthrodesis (OR 12.42) and immobile spine segments (OR 2.96) after DDS surgery. The older (> 60 years) group consisted of significantly more patients with facet arthrodesis and spinal segment immobility after DDS than the younger group ($p < 0.001$ and $p = 0.047$, respectively).

TABLE 1. Clinical and demographic characteristics*

Characteristics	Value
No. of patients	70
Sex	
M	39 (55.7)
F	31 (44.3)
Age in yrs, mean $\pm$ SD	64.0 ± 15.3
Duration of follow-up in mos, mean $\pm$ SD	29.9 ± 8.3
Smoking	8 (11.4)
Diabetes mellitus	16 (22.9)
Bridged level	
1	27 (38.6)
2	43 (61.4)

* Values are number of patients (%) unless otherwise indicated.

FIG. 1. Pie charts showing the distribution of the indexed levels for 1- and 2-level DDS.

Complications

During follow-up, 1 patient (1.4%) in the series had an infection and underwent reoperation to remove the implants 3 years after the DDS surgery. This patient remained free of symptoms related to spinal stenosis and had satisfactory clinical outcomes up to 60 months of follow-up. No other secondary surgery, including revision for malpositioned or loosened implants, revision to spinal fusion, or decompression for stenosis caused by adjacent-segment disease (ASD), were performed during the follow-up period.

The radiographic ASD, defined as a new development of reduction of disc height, greater than 3 mm vertebral translation, or greater than 5° decrease of disc angle,^{14,19} was approximately 17% at the average follow-up of 29.9 months after the operation. There were 12 (17.1%) of 70 patients who had radiographic evidence of ASD in the current series. In a subgroup analysis, there were 7 (18.4%) of 38 patients with facet arthrodesis who had radiographic ASD, while 5 (15.6%) of 32 patients without facet arthrodesis had radiographic evidence of ASD. There was no significant difference with respect to the incidence of

radiographic ASD between the patients with radiographic fusion and those without (whether or not they had facet arthrodesis) ($p = 0.506$) (Table 4).

Discussion

The current study analyzed 70 patients with lumbar spinal stenosis who underwent decompression and DDS. A total of 113 disc levels and 226 facet joints were bridged with the Dynesys pedicle screws and connected with elastic cords and spacers. During the average duration of follow-up of at least 2 years, unintended facet arthrodesis was identified by CT in 38 patients (54.3%), and 27 of them (38.6% of the entire series) had spinal segmental ROM less than 3° at the indexed level. In other words, only 61.4% of patients who underwent DDS actually had preserved motion in the lumbar spine after 2 years. Interestingly, the short- to midterm clinical outcomes of patients in the current series remained satisfactory regardless of facet fusion or not.

This is the first report to address unintended facet arthrodesis after DDS and its clinical correlation. The re-

FIG. 2. Twelve-month postoperative images obtained in a 47-year-old woman who underwent decompression and DDS at L4-5. **A and B:** Dynamic lateral radiographs showing flexion and extension. **C-E:** CT scans showing unintended facet arthrodesis at L4-5 bilaterally (white arrows).

FIG. 3. Twelve-month postoperative images obtained in a 68-year-old woman who underwent decompression and DDS at L4–5. **A and B:** Dynamic lateral radiographs showing flexion and extension. **C–E:** CT scans showing bilateral facet joints at L4–5. Preserved joint spaces are evident on both sagittal and axial images (white arrows).

sults provide a reasonable explanation for the limited segmental ROM after DDS reported in previous studies. The dynamic stabilization devices yielded fixation of spinal segments rather than preservation of physiological motion. The claimed design rationale of maintaining motion might not be achieved in many cases.

The DDS was designed to unload the disc space and

maintain spinal motion to a certain degree. The results have been demonstrated in previous reports both in vivo and in vitro.^{5,6,10,13,20,23,28,29} However, this controlled segmental spinal motion was never tested specifically in long-term follow-ups. Schnake et al. reported that 13 (54.2%) of 24 patients who underwent 1-level DDS demonstrated less than 3° of segmental motion at 2-year follow-up, and only

TABLE 2. Comparison of data between patients who developed unintended facet arthrosis and those who did not

Characteristic	Total	Facet Arthrosis		p Value
		Yes	No	
No. of patients	70	38 (54.3%)	32 (45.7%)	
Age in yrs, mean $\pm$ SD	64.0 $\pm$ 15.3	68.3 $\pm$ 13.8	58.5 $\pm$ 15.8	0.009*
Sex, no.				0.634
M	39	20	19	
F	31	18	13	
Level, no.				0.088
1	27	11	16	
2	43	27	16	
Immobile, no.				<0.001*
Yes	30	27	3	
No	40	11	29	
Segmental ROM in degrees				
Mean $\pm$ SD	4.9 $\pm$ 3.3	3.7 $\pm$ 3.3	6.3 $\pm$ 2.6	<0.001*
Range	0–16	0–16	0–13	
Mean preop scores, mean $\pm$ SD				
VAS back pain	4.8 $\pm$ 3.0	4.2 $\pm$ 3.0	5.5 $\pm$ 2.9	0.080
VAS leg pain	6.0 $\pm$ 2.8	5.6 $\pm$ 2.9	6.4 $\pm$ 2.6	0.258
ODI	52.1 $\pm$ 17.7	48.8 $\pm$ 15.7	56.1 $\pm$ 19.5	0.090
JOA	4.5 $\pm$ 3.1	4.6 $\pm$ 3.1	4.3 $\pm$ 3.1	0.654
Mean 24-mo postop scores, mean $\pm$ SD				
VAS back pain	2.4 $\pm$ 2.6	2.6 $\pm$ 2.6	2.2 $\pm$ 2.6	0.456
VAS leg pain	2.4 $\pm$ 2.6	2.8 $\pm$ 2.6	2.1 $\pm$ 2.5	0.267
ODI	20.4 $\pm$ 14.9	20.4 $\pm$ 15.5	20.3 $\pm$ 14.5	0.965
JOA	9.9 $\pm$ 3.4	9.7 $\pm$ 3.6	10.1 $\pm$ 3.1	0.608

* Indicates statistical significance, $p < 0.05$.

TABLE 3. Comparison of data between patient groups stratified by age

Characteristic	Total	Patient Age		p Value
		≤60 Yrs	>60 Yrs	
No. of patients	70	23	47	
Age in yrs, mean ± SD	64.0 ± 15.3	49.5 ± 10.3	72.4 ± 6.3	<0.001*
Facet arthrodesis, no. (%)				<0.001*
No	32	19 (82.6)	13 (27.7)	
Yes	38	4 (17.4)	34 (72.3)	
Immobile, no. (%)				0.047*
No	40	17 (73.9)	23 (48.9)	
Yes	30	6 (26.1)	24 (51.1)	

* Indicates statistical significance, $p < 0.05$.

5 (21%) of them had segmental motion of more than 5°. ²⁷ A published study of ours demonstrated that the DDS allowed only limited motion (i.e., 3°) in an average follow-up of approximately 3.5 years of 38 patients. ⁸ Furthermore, Schaeren et al. reported in their series that the mean segmental motion was only 3° at 4-year follow-up, and there were only 3 (15.8%) of 19 patients who had segmental motion of more than 5°. ²⁶ While these previously published series were of smaller numbers, the current study clearly demonstrates compatible results of limited spinal motion and has discovered a possible etiology of facet arthrodesis in a larger number of patients.

Preoperative and postoperative CT was undertaken for every patient in the series. Facet arthrodesis after DDS was confirmed by CT during follow-up in 38 patients of this series. Among the 38 patients with facet arthrodesis, there was a total of 130 facet joints stabilized by DDS. All 130 facet joints demonstrated preserved joint space with variable degrees of ossification evident on preoperative CT. At the end of this study, more than half (58.5%) of the 130 facet joints became fused, which demonstrated obliteration of the joint space of the facet and the formation of continuous cortical calcification, as indicated on follow-up CT. Although the joint capsule was kept intact during the operation and no bone grafts were inserted, the joint space was still replaced with partial calcification or total ossification. The finding thus explained the immobility in the current series, and little segmental ROM was demonstrated in 27 of these 38 patients. The risk factors of facet arthrodesis were unclear, and the patient sex and number of levels stabilized were not significant (Table 2).

Unintended facet arthrodesis did not affect clinical outcomes in the present series. Similar to previously published studies, patients with screw loosening after DDS had clinical outcomes as good as patients without screw loosening. During 2 to 4 years of follow-up, all patients' VAS scores for back and leg pain, ODI scores, and JOA scores improved, regardless of Dynesys screw loosening. ^{8,16,32} The loosened screws remained stable, which could be understandable if many of these facets had been fused spontaneously. However, further studies are necessary to verify this explanation.

TABLE 4. Correlation between facet resection, ROM, and ASD and facet arthrodesis*

Characteristic	Facet Arthrodesis		p Value
	Yes	No	
Facet resection vs preservation			0.435
Partial resection	1	2	
Preservation	37	30	
ROM			0.278
ROM ≤16.9°	20	20	
ROM >16.9°	18	12	
ASD			0.506
Present	7	5	
Absent	31	27	

* Values are number of cases.

Schnake et al. reported on 24 patients with degenerative spondylolisthesis who were treated with DDS. There was no progression of spondylolisthesis, and the stabilized lumbar segments appeared immobile (< 3° ROM) at 2-year follow-up. These 24 patients had clinical improvement of pain scores, walking distances, and analgesic usage. ²⁷ Schaeren et al. followed 26 patients for more than 4 years and demonstrated that DDS could achieve clinical improvement in patients with degenerative spondylolisthesis and spinal stenosis. The report indicated that DDS treatment could stop the progression of spondylolisthesis by providing sufficient stability at the indexed levels (limited ROM of 3°). ²⁶ Both of the above articles did not address the cause of these immobile spinal segments without bone grafts implanted (attempted arthrodesis) during the operation.

In the past decade instrumented facet fusion has been reported as an option for lumbar fixation. For example, Park et al. reported on 99 patients with lumbar spondylolisthesis who underwent instrumented facet fusion for spondylolisthesis. The overall fusion rate was 96%, and most patients obtained satisfactory clinical outcomes. Thus, fusion of facet joints was likely to provide sufficient strength to stabilize spondylolisthesis at 2-year follow-up. ²² There were also reports of facet screw fixation, including stand-alone facet screws or in combination with contralateral pedicle screws for lumbar interbody fusion. ^{3,15}

Best and Sasso demonstrated success in using trans-laminar facet screws for circumferential interbody fusion in 43 patients at 2-year follow-up. ³ Therefore, facet arthrodesis has demonstrated its effect of stabilization in the spondylotic lumbar spine. The unintended facet arthrodesis reported in the current series is likely a very reasonable explanation for the satisfactory outcomes of the DDS in the management of degenerative spondylolisthesis.

In the current series, sex composition and the number of stabilized vertebral segments were not significantly different between the 2 patient groups. The mean age of patients with facet arthrodesis was 9.8 years older than those who did not have facet arthrodesis (58.5 years vs 68.3 years, $p = 0.009$). This implies that the aging process may be strongly correlated with facet arthrodesis after DDS. The older the patient the higher the rate of facet arthrodesis (less motion preservation) after DDS. This may

FIG. 4. Bar graphs showing the VAS scores for back pain (A) and leg pain (B), ODI scores (C), and JOA scores (D) at each time point of observation. There were significant improvements postoperatively when compared with that accessed preoperatively ($p < 0.05$ at each time point). The numbers indicate the mean value of each score.

also indicate that facet arthrodesis happens in later stages and is a more severe form of lumbar spondylosis. However, we suspected that there could be some other factors that impact on the facet joints. Further studies are needed to analyze factors such as diabetes mellitus, smoking, and osteoporosis. Patients who were older than 60 years had a much higher risk of facet arthrodesis and postoperative immobile spine. The odds ratios were 12.42 for those older than 60 years and 2.96 for those 60 years and younger. We think these radiological manifestations had an impact on clinical outcomes to some degree, although the current study could not prove it.

Our previous study in 2013 demonstrated that, in patients with or without spondylolisthesis, the Dynesys system could provide satisfactory clinical outcomes and sufficient stability at a mean of 41.4 months follow-up.⁸ The 27 disc levels with spondylolisthesis were found to have a significant decrease in translation percentage from 13.9% to 10.1%. This reduction and stabilization may contribute to facet arthrodesis. The study demonstrated that DDS preserved only restricted segmental motion ($\leq 3^\circ$) by the construct of pedicle screws, posterior polymer spacers, and tension cords. According to the current study, it is reasonable to infer that the restricted segmental mobility was likely caused by the ossified facet joints. Partial obliteration of the facet synovial joint space will lead to motion preservation to some degree, while complete arthrodesis will lead to total alleviation of segmental motion.

Another retrospective study included 72 patients with lumbar spondylosis who underwent decompression and DDS; it demonstrated the rehydration of the intervertebral disc.⁷ The T2-weighted MRI signals of discs increased significantly in younger patients at the mean follow-up of 46.7 months. The Dynesys system was designed to shift the load from the intervertebral disc to the artificial spacer and cord. That study corroborated the original design of the dynamic stabilization system. However, the load shifting to posterior elements may cause progressive facet joint ossification. The relation between disc rehydration and facet arthrodesis is not clear and may need to be clarified in future studies.

There are limitations to this study. This was a retrospective analysis of 70 consecutive patients who underwent DDS and were followed-up for more than 24 months. The reported incidence of unintended facet arthrodesis at 54.3% of patients was based on the assessment of postoperative CT scans. Although a larger number of patients are needed to yield a more accurate estimation of the incidence rate, this is the first report to disclose unintended facet fusion. The cases of facet arthrodesis reported here were all confirmed by CT and correlated with limitation in lumbar spinal motion. However, there were no investigations into the causes and biomechanical effects of the phenomenon of unintended facet arthrodesis. The DDS operations of this study did not involve any bone grafts for fusion and were intended to preserve lumbar spinal motion, which

was not achieved in 38.6% of the patients (27 patients had ROM < 3°). The study was not able to demonstrate the cause or time of the occurrence of facet arthrodesis. The merit of this article is to report for the first time this unintended result of fusion in facet joints and thus provide information on outcomes in these dynamically stabilized patients.

The surgical techniques used in the present series did not involve facet violation or any bone grafting across the bridged joints. The true cause of this unexpected facet arthrodesis remains elusive. However, there was limited ROM in many patients of the present series, and those fused facets were all confirmed on CT scans during the follow-up period. Therefore, the rationale of preservation of spinal segmental motion assigned to the DDS appears questionable. Furthermore, the long-term outcome of DDS and its effect on preservation of spinal segmental ROM requires extended and larger scale studies to verify.

Conclusions

During the follow-up period of more than 2 years, unintended facet arthrodesis was demonstrated in 54.3% of the patients who underwent 1- or 2-level DDS. Patients over 60 years were more likely to have this unintended facet arthrodesis and subsequent immobile spinal segments. However, the unintended facet arthrodesis did not affect the clinical outcomes during the study period. Further evaluations are needed to clarify the actual significance of this phenomenon.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: JC Wu, Fay, Cheng. Acquisition of data: Wang, Tsai. Analysis and interpretation of data: Tsai. Drafting the article: Fay, PY Chang, Wang. Critically revising the article: JC Wu. Reviewed submitted version of manuscript: PY Chang, Huang, Tu. Statistical analysis: Tsai, HK Chang. Administrative/technical/material support: CL Wu. Study supervision: JC Wu, Fay, Huang, Cheng.

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