RESEARCH ARTICLE

Dynamic Rod Constructs as the Preventive Strategy against Adjacent Segment Disease in Degenerative Lumbar Spinal Disorders: A Retrospective Comparative Cohort Study

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Abstract

Objectives: Adjacent segment degeneration (ASDe) and adjacent segment disease (ASDi) are potential long-term complications after lumbar fusion with rigid instrumentation. Dynamic fixation techniques (Topping-off) adjacent to the fused segments have been developed to curtail the risk of ASDe and ASDi. The current study sought to investigate whether the addition of dynamic rod constructs (DRC) in patients with preoperative degeneration in the adjacent disc was effective in reducing the risk of ASDi.

Methods: A retrospective analysis was performed on clinical data of 207 patients with degenerative lumbar disorders (DLD) from January 2012 to January 2019, who underwent posterior transpedicular lumbar fusion (without Topping-off, NoT/O), and posterior dynamic instrumentation with DRC. Clinical and radiological outcomes were evaluated using Oswestry Disability Index (ODI), Visual Analogue Scale (VAS), and lumbar radiographs one, three, and 12 months postoperatively and annually. ASDe was defined as disc height collapse > 20% and disc wedging > 5. Patients with confirmed ASDe and aggravation of ODI > 20 or VAS score > 5 at final follow-up were diagnosed as ASDi. The Kaplan-Meier hazard method was used to estimate the cumulative probability of ASDi within 63 months of surgery.

Results: Over three years of follow-up, 65 patients in the NoT/O (59.6%) and 52 cases (53.1%) in the DRC groups met the diagnostic criteria for ASDe. Furthermore, 27 (24.8%) patients in the NoT/O group showed ASDi during the follow-up, compared to 14 (14.3%) cases in the DRC group (*P*=0.059). Revision surgery was performed on 19 individuals in the NoT/O and 8 cases in the DRC groups (*P*=0.048). The Cox regression model identified a significantly decreased risk of ASDi if DRC was used (Hazard ratio: 0.29; 95% CI: 0.13-0.6).

Conclusion: Dynamic fixation adjacent to the fused segment is an effective strategy for preventing ASDi in carefully selected individuals with preoperative degenerative changes at the adjacent level.

Level of evidence: II

Keywords: Adjacent segment disease, Degenerative lumbar spinal disorders, Dynamic fixation, Lumbar instrumentation, Rigid fixation

Introduction

Lumbar fusion has been demonstrated to be an important treatment option, [1] and it can improve functional outcomes in carefully selected symptomatic individuals with different degenerative lumbar disorders (DLD). [2, 3] despite favorable clinical outcomes of fusion surgery, complications of utilizing rigid instrumentation have raised concerns over the past years. [4,5] Adjacent segment degeneration (ASDe) and adjacent segment disease (ASDi) are deemed to be potential long-term complications subsequent to rigid spinal fixation, which can develop due to biomechanical changes, such as an increase in range of motion and intradiscal pressure at

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the upper segment adjacent to the fused level. [3,6] The rate of ASDe in previous literature was reported 18.6% (ranging from 8.5% to 69.4%), depending on the sample size and follow-up duration, [7] and the incidence of ASDi varied from 5.2% to 36.1% after 10 years of follow-up. [8] Moreover, it is reported that ASDe of the segment superior to the fused level occurred in up to 80% of the patients after lumbar fusion. [9,10] In this regard, it is crucial for surgeons to meticulously evaluate the adjacent disc above the fused segments so as to reduce the risk of ASDe. [3]

The addition of dynamic instrumentation devices, either pedicle screw- or rod-based, adjacent to the fused segment (Topping-off technique) has shown to be effective in preserving the mobility of the instrumented segments, thereby lessening the risk of ASDe in the adjacent segment. [5, 6] The rationale behind using Topping-off techniques is that the semi-rigid zone maintains a gradual transition between the caudal rigid fused level and the unfused cephalad-mobile segments to reduce the pressure concentrated at the adjacent level. [5,6] This considerably contributes to imitating the physiologic behavior of the spine [11] Baioni et al. [12] and Maserati et al. [13] reported satisfactory patient-related outcomes following the use of pedicle screw-based dynamic devices (Dynesys Transition Optima device [Zimmer Spine Inc., Denver, Colorado, USA]) for DLD. By contrast, Putzier et al. [14] and Lee et al. [15] showed that clinical improvement between dynamic instrumentation and only fusion groups did not differ significantly. A recent comparative study by Fuster et al. [6] on rigid and dynamic stabilization revealed promising results in favor of the application of the Topping-off technique with dynamic rod constructs (DRC). Although they showed that DRC decreased the risk of ASDi, their results could not corroborate previous studies owing to their short-term follow-up and low sample size.

As a result, the preventive role of posterior dynamic devices immediately above the fused level from symptomatic ASDi has remained a contentious matter amongst spine surgeons. This study sought to compare posterior transpedicular lumbar fusion (without Topping-off, NoT/O), and posterior dynamic instrumentation with DRC in terms of clinical and radiological outcomes in patients with some degree of preoperative degeneration in the disc adjacent to the fusion segment.

Materials and Methods

Patients

This retrospective clinical and radiological assessment comprised all patients diagnosed with a degenerative lumbar spinal disease and underwent posterior transpedicular lumbar fusion with (DRC) or without the Topping-off technique (NoT/O) between January 2012 and January 2019 [Figure 1]. From 2012 onwards, DRC was commenced to be used in our center. To determine the lower limit of our sample size, the following formula was used to compare two proportions $[n=(Z_{\alpha/2}+Z_{\beta})^2 * (p_1(1-p_1)+p_2(1-p_2)) / (p_1-p_2)^2]$.[16] Where $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (e.g., for a confidence level of 95%, α is 0.05, and the critical value is 1.96), Z_{β} signifies the critical value of the normal distribution at β (e.g., for a power of 80%, β is 0.2, and the critical value is 0.84), and p_1/p_2 present the expected sample proportions of the two groups. According to the most recent similar study, [6] p_1 and p_2 were 0.042 and 0.20, respectively. To provide a longer follow-up, compared to former studies, patients with a history of fusion surgery of fewer than 36 months were excluded. All the surgeries were performed over the same interval by an experienced spine surgeon in Razavi Hospital, Mashhad, Iran.

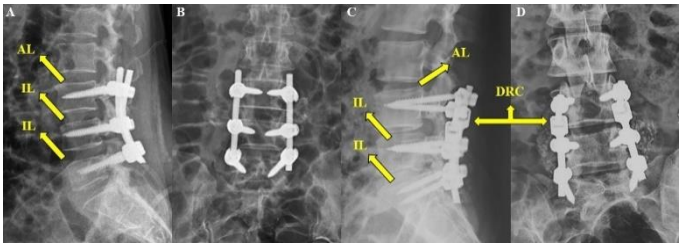

Figure 1. (A) and (B) Posterior transpedicular lumbar fusion without Topping-off technique. (C) and (D) Dynamic stabilization as the Topping-off technique with DRC (FRADIS Medical Inc, Salouël, France). IL: Index level; AL: Adjacent level; DRC: Dynamic rod construct

The inclusion criteria were as follows: (1) radiculopathy or axial pain with the lumbar origin, (2) follow-up duration of more than 36 months with complete pre-and postoperative clinical and radiological evaluation, (3) single- or two-level lumbar fusion, (4) preoperative Pfirrmann grade of ≥ three [17, 18] on magnetic resonance imaging (MRI) for the adjacent disc above the fused level, and (5) no response to conservative treatment for > six months. On the other hand, the exclusion criteria were a history of osteoporosis or metabolic bone disease, vertebral fracture adjacent to the fusion level, and preoperative Oswestry Disability Index (ODI) ≤ 20. [6]

Of 226 patients who fulfilled the eligibility criteria, 19 individuals were removed from the study on account of incomplete clinical or radiological follow-up. Moreover, Patients' characteristic data, including age, gender, body mass index (BMI), prior history of diabetes or hypertension, as well as type and duration of the symptoms, were collected. This study was approved by the Local Ethics Committee of AJA University of Medical Sciences (Approval ID: IR.AJAUMS.REC.1401.028) and was conducted based on the ethical standards of the 1964 Declaration of Helsinki. Informed written consent was obtained from all the participants.

Clinical and radiological assessment

The preoperative clinical and radiological evaluations were performed through a neurological examination, ODI, Visual Analogue Scale (VAS), lumbar MRI, as well as standing and dynamic lumbar X-ray. At follow-up visits, ODI for functional status, [19] VAS for low back pain and radicular leg pain, [20,21] and lumbar radiographs were conducted one, three, and 12 months postoperatively and annually thereafter. In cases of recurrent symptoms subsequent to the surgery, MRI was performed to evaluate the need for revision surgery. Preoperative lumbar disc degeneration and end plate changes were analyzed using Pfirrmann and Modic classification scales, respectively. Radiographic parameters, such as lumbar lordosis (L1-S1 Cobb's angle), pelvic incidence, pelvic tilt, sacral slope, the adjacent disc height, and segmental Cobb's angle were measured pre-and postoperatively.

The adjacent segment was considered the segment above the fused vertebrae or the segment with dynamic instrumentation in case of using the Topping-off technique [Figure 1]. Postoperative ASDe were defined as follows: (1) disc height collapse > 20% and (2) disc wedging > 5°. [10, 14] Furthermore, patients were diagnosed with ASDi in case of confirmed ASDe as per the above criteria and aggravation of postoperative ODI > 20 or VAS (leg/back pain) score > five at final follow-up. [6]

Surgical procedure

All the surgeries were conducted with the patient in a prone position under general anesthesia. A standard midline incision was done over the spinous processes of the lumbar vertebrae, separating subperiosteal muscles bilaterally. Laminectomy with foraminal decompression, facetectomy, and discectomy was performed to adequately decompress the neural elements prior to pedicle screw fixation. Real-time fluoroscopy was utilized to achieve the accurate placement of pedicle screws. In cases of using dynamic rods (FRADIS Medical Inc, Salouël, France), pedicle screws were placed lateral to the facet joints to avert facet joint violation.

Statistical analysis

Continuous variables are shown as mean±SD or median and interquartile range (IQR) values and were compared using the Student *t*-test or the Mann-Whitney *U*-test as per the Kolmogorov-Smirnov test of normality. Qualitative variables were described using absolute frequencies and percentages and were compared using the chi-square test or Fisher's exact test, when necessary. McNemar and Wilcoxon tests were also utilized for continuous and qualitative variables, respectively, to compare paired preoperative and postoperative data. The Kaplan-Meier hazard method was applied to estimate the cumulative probability of ASDi within 63 months of surgery. The log-rank test was performed to compare hazard curves. A logistic regression model was employed to identify independent variables related to ASDe, and a Cox regression model was performed to identify independent variables related to ASDi. The presence of interaction and the role of confounding factors were assessed. Statistical analyses were performed using SPSS software (version 26, SPSS Inc., Chicago, Illinois, USA). Statistical significance was defined as a *P*-value less than 0.05.

Results

Descriptive data

In total, data from 207 patients were used in this study. Of them, 109 (52.7%) individuals underwent posterior transpedicular lumbar fusion without the Topping-off technique (NoT/O group), while the other (n=98; 47.3%) underwent fusion with dynamic stabilization (DRC group). The mean±SD age of the patients was 56.9±6.3 years, and 56% of the cases were female. The baseline characteristics of the subjects are summarized in [Table 1]. In total, 49 (23.7%) patients received single-level fusion (L3-L4 in five cases, L4-L5 in 29 cases, and L5-S1 in 15 cases), and 158 (76.3%) subjects received two-level fusion (L2-L4 in 14 cases, L3-L5 in 36 cases and L4-S1 in 108 cases). The mean (SD) BMI of the cohort was 27.29 kg/m2, and 77 (37.2%) patients were smokers. Moreover, 21 (10.1%) and 58 (28%) patients suffered from lumbar pain and radiculopathy, respectively, while 128 (61.8%) cases complained of both symptoms. The preoperative mean±SD values of ODI and VAS scores were 68.67±13.62 and 7.14±1.79, respectively. The preoperative Pfirrmann grade of ≥ three at index and the adjacent level was observed in 192 (92.8%) and 45 (21.7%) patients, respectively. Modic changes prior to the surgery were seen in 136 (65.7%) subjects. Spondylolisthesis was present in 114 (55.1%) cases with a median of 18% (IQR, 15%-20%) in the percentage of listhesis.

Clinical and radiological outcomes

The preoperative mean±SD disc height at the adjacent level was 7.69±0.90 mm. The mean±SD values of L1-S1 Cobb's angle, pelvic incidence, pelvic tilt, and sacral slope were 50.61°±6.54°, 58.81°±6.77°, 22.93°±5.11°, and 36.53°±4.37°, respectively. The average preoperative and final follow-up L1-S1 Cobb's angle (50.61°versus 51.41°), pelvic incidence (58.81° versus 59.54°), pelvic tilt (22.93° versus 25.00°), and sacral slope (36.53° versus 36.22°) are shown according to the type of instrumentation [Table 2].

In this regard, there was a significant difference between the NoT/O and DRC groups regarding the sacral slope (37.84° versus 34.42°, *P*<0.001).

Table 1. Comparison of patients' characteristics between NoT/O group and DRC group

Baseline characteristic		NoT/O group (n=109)	DRC group (n=98)	*P*-value *
Age (year)		57.0±6.9	56.7±5.6	0.898
Female		61 (56%)	55 (56.1%)	0.982
Body mass index (kg/m2)		27.9±3.0	26.6±3.8	0.005
Smokers		40 (36.7%)	37 (37.8%)	0.875
Symptoms prior to surgery	Lumbar pain	12 (11%)	9 (9.2%)	0.907†
	Radicular symptoms	30 (27.5%)	28 (28.6%)	
	Both lumbar and radicular	67 (61.5%)	61 (62.2%)	
Duration with symptoms (months)		23.6±7.7	25.8±7.4	0.047
Type of vertebral fusion				0.042‡
- Single fusion		32 (29.4%)	17 (17.3%)	

Table 1. continued				
- Two-level fusion		77 (70.6%)	81 (82.7%)	0.42
- Length of fusion	L5–S1	11 (10.1%)	4 (4.1%)	
	L4–L5	18 (16.5%)	11 (11.2%)	
	L3–L4	3 (2.8%)	2 (2%)	
	L4–S1	53 (48.6%)	55 (56.1%)	
	L3–L5	18 (16.5%)	18 (18.4%)	
	L2–L4	6 (5.5%)	8 (8.2%)	
Pffirmann preoperative	Index level	100 (91.7%)	92 (93.9%)	0.554
classification >3 at	Adjacent level	11 (10.1%)	34 (34.7%)	0 < 0.001
Modic changes >1 before surgery		79 (72.5%)	57 (58.2%)	0.030
Spondylolisthesis before surgery		66 (60.5%)	48 (48.9%)	0.095
Listhesis§ %		17.2±4.0	16.5±4.0	0.335

Statistically significant differences are shown in bold. NoT/O: Not topping-off; DRC: Dynamic rod construct; * NoT/O group and DRC group were compared. † Pearson's χ2 P-value with 2 degrees of freedom to test the data distribution of all type of symptomatology. ‡ Pearson's χ2 P-value with 5 degrees of freedom to test the data distribution of all type of vertebral fusion. § Calculated among patients with spondylolisthesis (n=114)

In addition, there was not a significant difference in the disc height at the adjacent level between NoT/O and DRC groups over the follow-up period [Table 2]. After a median follow-up of 50 months (IQR, 44-56 months), progression of ASDe was observed in 117 (56.5%) individuals whilst 41 (19.8%) cases presented with ASDi (as per the criteria discussed in the "Methods" section). Of them, 27 (12.9%) cases were unresponsive to conservative treatment and required revision surgery [Table 3].

Table 2. Comparison of radiographic parameters between NoT/O group and DRC group at the adjacent segment

	NoT/O group (n=109)	DRC group (n=98)	*P*-value*
Mean L1-S1 Cobb's angle (°)			
Preoperative	50.46±6.75	50.79±6.54	0.515
1 month postoperative	48.16±6.47	46.72±6.34	0.212
Last follow-up	52.12±6.74	50.62±6.25	0.172
Mean PI (°)			
Preoperative	59.37±7.44	58.20±6.72	0.319
1 month postoperative	59.16±5.85	57.73±6.50	0.225
Last follow-up	60.20±5.02	58.81±5.84	0.255
Mean PT (°)			
Preoperative	23.43±5.54	22.38±5.07	0.132
1 month postoperative	22.23±4.74	21.39±4.34	0.165
Last follow-up	24.66±4.01	25.39±4.01	0.167
Mean SS (°)			
Preoperative	36.78±4.46	36.26±4.37	0.505
1 month postoperative	38.09±3.42	37.44±3.62	0.241
Last follow-up	37.84±3.84	34.42±4.45	< 0.001
Mean segmental angle (°)			
Preoperative	8.81±1.21	8.99±1.18	0.258
1 month postoperative	7.48±1.34	7.80±1.38	0.108
Last follow-up	9.79±1.70	9.37±1.67	0.133
Mean disc height (mm)			
Preoperative	7.70±0.89	7.68±0.92	0.822
1 month postoperative	7.78±0.87	7.75±0.89	0.846
Last follow-up	6.51±0.84	6.49±0.82	0.821

Statistically significant differences are shown in bold. NoT/O: Not topping-off
DRC: Dynamic rod construct group
PI: Pelvic index
PT: Pelvic tilt
SS: Sacral slope; * NoT/O group and DRC group were compared

Table 3. Comparison of outcomes between NoT/O group and DRC group

Outcomes	NoT/O group (n=109)	DRC group (n= 98)	*P*-value*
Follow-up (months)	50.0±6.7	50.7±7.9	0.546
Bleeding during surgery (mL)	402.3±394.2	294.8±65.0	0.774
Duration of surgery (min)	217.0±25.9	221.3±22.5	0.620
ASDe at last follow-up	65 (59.6%)	52 (53.1%)	0.341
ASDi at last follow-up	27 (24.8%)	14 (14.3%)	0.059
Revision surgery due to ASDi	19 (17.4%)	8 (8.2%)	0.048

Statistically significant differences are shown in bold. NoT/O: Not topping-off; DRC: Dynamic rod construct; ASDe: Adjacent segment degeneration; ASDi: Adjacent segment disease; * NoT/O group and DRC group were compared

The medium preoperative and final VAS scores (7.1 and 3.1) and ODI (68.6 and 28.24) according to the type of surgery are shown with a significant worsening in the clinical outcome in the NoT/O group versus DRC in both the scales [Figure 2].

The trend of changes in radiological and clinical parameters of both surgical groups was assessed. There was a significant difference between the two groups in terms of mean L1-S1 Cobb's angle differentiation at 1 month postoperatively and last follow-up. Mean pelvic tilt, sacral slope, and segmental angle differentiation between NoT/O and DRC groups did significantly differ at the last follow-up. Furthermore, there was a substantial difference between the two groups in terms of mean VAS and ODI differentiations at the last follow-up [Table 4].

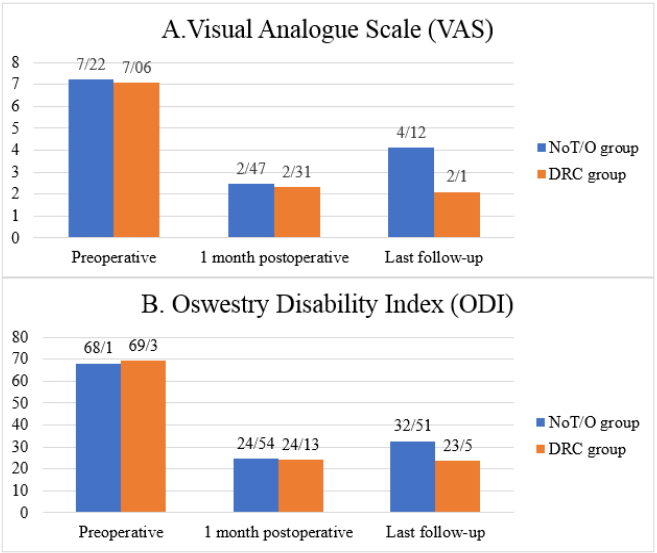

Figure 2. (A) Median Visual Analog Scale (VAS) and (B) Oswestry Disability Index (ODI) measured preoperatively, 1 month postoperative, and at last follow-up, as per the group of treatment: NoT/O: Not Topping-off; DRC: Dynamic rod construct

Table 4. Comparison of changes in radiographic and clinical parameters between NoT/O group and DRC group at the adjacent segment

	NoT/O group (n=109)	DRC group (n=98)	*P*-value*
Radiographic parameters			
Mean L1-S1 Cobb's angle differentiation (°)			
1 month postoperative	-2.30±0.91	-4.06±1.29	<0.001
Last follow-up	1.66±3.01	-0.16±7.97	0.035
Mean PI differentiation (°)			
1 month postoperative	-0.21±9.09	-0.46±9.05	0.838
Last follow-up	0.83±9.20	0.60±8.94	0.854

Table 4. continued

Mean PT differentiation (°)			
1 month postoperative	-1.20±2.01	-0.98±2.23	0.473
Last follow-up	1.22±6.18	3.02±1.86	0.005
Mean SS differentiation (°)			
1 month postoperative	1.31±2.82	1.18±5.38	0.833
Last follow-up	1.06±2.41	-1.83±2.49	<0.001
Mean segmental angle differentiation (°)			
1 month postoperative	-1.33±1.01	-1.18±1.76	0.488
Last follow-up	0.96±1.30	0.38±1.96	0.014
Mean disc height differentiation (mm)			
1 month postoperative	0.06±0.56	0.07±0.58	0.958
Last follow-up	-1.19±0.94	-1.19±91	0.987
Clinical parameters			
Mean VAS differentiation			
1 months postoperative	-4.75±2.69	-4.74±2.08	0.982
Last follow-up	-3.10±3.01	-4.95±2.33	<0.001
Mean ODI differentiation			
1 months postoperative	-43.55±15.95	-45.17±14.26	0.446
Last follow-up	-35.58±15.82	-45.80±13.96	<0.001

Statistically significant differences are shown in bold. NoT/O: Not topping-off, DRC: Dynamic rod construct group; PI: Pelvic index, PT: Pelvic tilt, SS: Sacral slope; VAS: Visual analog scale; ODI: Oswestry disability index; * NoT/O group and DRC group were compared

In addition, the cumulative hazard function of developing ASDi within 63 months is provided for each type of instrumentation [Figure 3]. Each variable in this cohort that was potentially associated with the progression and development of ASDe and ASDe was included in the multivariate analysis, revealing no independent variable related to ASDe at the adjacent level (logistic regression model) and a significantly decreased risk of ASDi if dynamic stabilization (DRC) was used (cox regression model) (Hazard ratio: 0.29; 95% CI: 0.13-0.66; P=0.003) [Table 5].

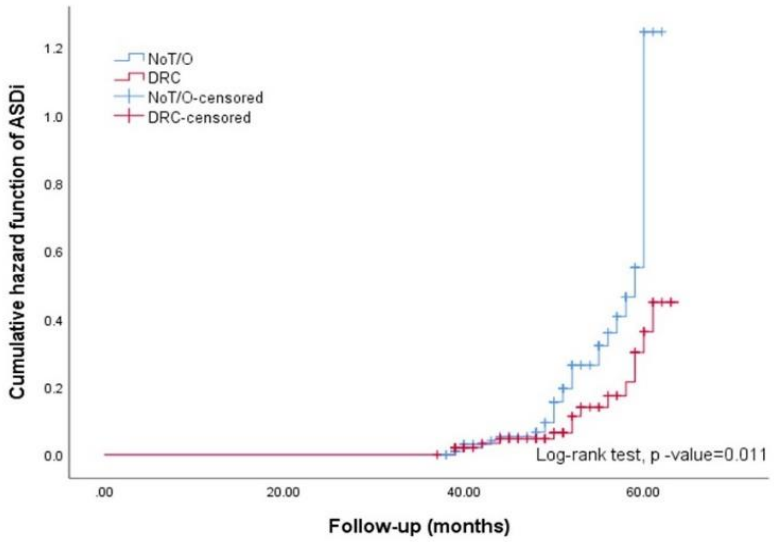

Figure 3. Cumulative hazard function of ASDi (as defined in the methods section) within 63 months after surgery according to the use of DRC as a topping-off technique. ASDi: Adjacent segment disease; DRC: Dynamic rod construct; NoT/O: Not Topping-off

Table 5. Logistic regression model and Cox regression model results considering ASDe and ASDi, respectively, as the dependent variable.

Variable	Logistic regression model (ASDe)		Cox regression model (ASDi)	
	OR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Age	1.01 (0.96–1.06)	0.582	1.01 (0.95–1.06)	0.757
Gender (female)	0.61 (0.31–1.22)	0.166	1.14 (0.55–2.34)	0.721
Body mass index	0.97 (0.89–1.06)	0.545	0.89 (0.79–1.00)	0.044
Smoker (yes)	1.46 (0.72–2.97)	0.295	0.83 (0.38–1.80)	0.618
Pffirmann preoperative classification of adjacent segment	0.82 (0.56–1.20)	0.305	0.91 (0.62–1.36)	0.670
Preoperative L1–S1 Cobb angle	1.00 (0.96–1.05)	0.948	0.99 (0.95–1.04)	0.973
Preoperative pelvic incidence	0.97 (0.92–1.01)	0.135	0.96 (0.91–1.01)	0.114
Preoperative pelvic tilt	1.06 (1.00–1.13)	0.035	1.04 (0.97–1.01)	0.206
Preoperative sacral slope	0.99 (0.93–1.07)	0.852	0.93 (0.87–1.01)	0.092
Disc height preoperative	0.69 (0.50-0.97)	0.032	0.80 (0.56–1.14)	0.218
Segmental angle preoperative	0.87 (0.68-1.13)	0.268	0.90 (0.68–1.18)	0.446
Using DRC (topping-off technique)	0.76 (0.42-1.38)	0.367	0.29 (0.13–0.66)	0.003

Statistically significant differences are shown in bold. ASDe: Adjacent segment degeneration; ASDi: Adjacent segment disease; OR: Odds ratio; CI: Confidence interval; HR: Hazard ratio; DRC: Dynamic rods construct; NoT/O: Not topping-off

Discussion

Lumbar fusion is a commonplace surgical method to treat patients with DLD. [22, 23] ASDe has been regarded as a major long-term complication affecting the success of posterior instrumentation and fusion. [24, 25] ASDe constitutes arthritic changes that happen to the vertebral segments adjacent to a lumbar instrumented fusion, whilst ASDi is a clinical condition presenting with low back pain and radiculopathy on account of these ASDe changes. [26] The occurrence of ASDe is likely to be multifactorial, and rigid spinal fixation has been perceived to be a significant contributing factor. [14, 27]

Over the past two decades, a wealth of lumbar dynamic devices and techniques (e.g., Topping-off techniques) have been developed so as to curtail the incidence of ASDe, compared to rigid spinal fixation. [28] Topping-off techniques refer to utilizing instrumented non-fusion techniques that provide a gradual transition between the fused rigid level and the cephalad-mobile unfused segments. [29, 30] Dynamic stabilization devices for the Topping-off technique are categorized into: (1) hybrid stabilization devices with pedicle screw or DRC, (2) interspinous process devices, and (3) total facet replacement systems. [11] It has been explicated that dynamic techniques can preserve flexion and lateral bending, restricting motions in extension; however, they cannot entirely compensate for increased rotational movement, compared to that in a normal spine. [31] Reduced intradiscal pressure at the adjacent level appears to be a compelling reason to consider dynamic stabilization as a preventive surgical method for degenerative disc changes. [32] There is a challenging situation for spinal surgeons when a disc adjacent to the fused segment is already degenerated, and they need to either accept the risk of ASDe by operating on index levels or stabilize all degenerated levels with the probability of shifting the degeneration to the superior level.

This study compared clinical and radiologic data of 98 patients with one- or two-level lumbar degenerative diseases who underwent a posterior transpedicular lumbar fusion with DRC in order to prevent ASDe, with the results of 109 patients who were surgically treated with lumbar fusion without dynamic instrumentation. To the best of our knowledge, this study is one of the fewest comparative cohorts investigating whether the addition of dynamic rod constructs, as a Topping-off technique, to the fused level, could prevent the development and progression of ASDe and ASDi in patients who underwent posterior lumbar fusion.

Although in vivo studies demonstrate that dynamic stabilization systems decrease stress loads to the adjacent level, several studies showed inconsistent results with the Topping-off technique, and no compelling evidence has been given regarding the clinical and radiological advantages of hybrid devices. [12-14,32,33] Even though Putzier et al. [14] reported that dynamic instrumentation could prevent radiological changes regarding the progression of a degenerated disc, they failed to distinguish any clinical distinction in the outcome.

Kashkoush et al. [30] showed that hybrid stabilization could only postpone degenerative changes of the adjacent segment and cannot prevent ASDe. Chen et al. [34] found that although the Topping-off technique reduced the incidence of ASDe in comparison with the

only fusion group, it could not preserve disc height, neural foramen height, and width of the adjacent segment during the follow-up.

A meta-analysis revealed that the incidence of ASDe in the motion-preservation group was 5.1%, whereas in the only fusion group it was 14.4%, and the reoperation rate on the adjacent level in the former was lower than that in the latter. [35] In line with pertinent literature, a systematic review by Chou et al. [3] revealed that ASDe, ASDi, and revision surgery had a significantly higher incidence. A recent meta-analysis by Wang et al. [36] compared all available data on postoperative clinical and radiographic outcomes of the Topping-off technique and posterior lumbar interbody fusion (PLIF) and showed that Topping-off techniques could play a pivotal role in preventing ASDe and ASDi from progressing after internal lumbar fixation. However, they report that this technique is more effective in improving the subjective feelings of patients rather than objective motor functions, compared to PLIF. The newest study on the preventive effect of such a technique launched by Fuster et al. [6] demonstrated that using DRC and ISD as Topping-off techniques could prevent the progression of ASDe and ASDi if applied at the adjacent level with preoperative degenerative changes. Beyond and above that, The World Federation of Neurosurgical Societies recommends that dynamic stabilization devices can be seen as an alternative that might help avert the occurrence of degenerative changes at the adjacent level. What should be noted is that there is a paucity of information regarding the definite efficacy of Topping-off techniques. [37]

In our study, all the cases had preoperative degenerative changes at the adjacent level; thus, the benefit of using DRC was analyzed as the Topping-off technique to prevent ASDe progression and ASDi occurrence. The overall rate of ASDe was 56.6%, with no significant difference between DRC and NoT/O groups. Nonetheless, it was inferred that DRC had a promising role in preventing ASDi development, and for the patients in the DRC group, it had more favorable clinical outcomes regarding the postoperative ODI and VAS scores. The prevalence of ASDi in our study was 19.8%, with a considerable difference between the two groups (DRC: 14.3%, NoT/O: 24.8%). These results are in mark contrast with those found in radiological findings because both groups had relatively similar rates of ASDe (DRC: 53.1%, NoT/O: 59.6%). Revision surgery was undertaken for 27 (13%) patients on account of intractable symptoms, and other cases diagnosed with ASDi had clinical improvement with conservative treatment [Figure 4].

In a study by Fuster et al., [6] the logistic regression model and Cox regression model explicated that higher degenerative disc changes, based on Pfirrmann classification, [17] is an independent risk factor associated with ASDe progression, whilst in our study, no contributing factor for ASDe progression was detected [Table 5]. In line with the pertinent research, [6] it was found that using DRC as the Topping-off technique was a preventive factor for the development of ASDi. It is worth noting that neither in our study nor Fuster et al. [6] gender, BMI, and smoking were not related to the study outcome.

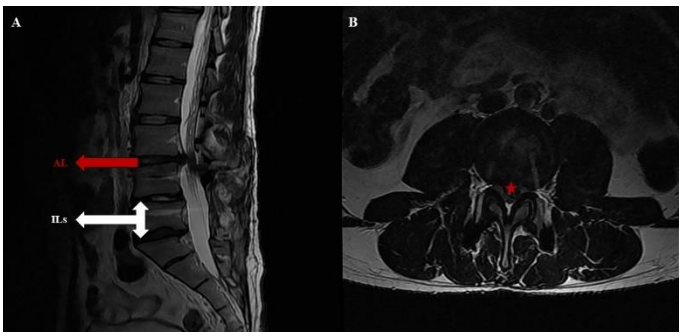

Figure 4. Sagittal (A) and coronal (B) MR images of a patient who underwent L4-S1 posterior transpedicular lumbar fusion and developed adjacent segment disease 51 months postoperatively. The red arrow and asterisk indicate an extruded disc into the spinal canal at the adjacent level. ILs: Index levels; AL: Adjacent level

Unlike similar studies, this study presents a comparison with a large number of patients who underwent a lumbar fusion with or without a Topping-off technique over a median follow-up of 50 months (IQR, 44-56 months) in order to substantiate previous findings. The main shortcoming of our study was the retrospective design. Moreover, the patient selection was not randomized; therefore, the risk of bias might be increased. Thus, further prospective randomized studies are highly recommended so as to help provide strong evidence regarding the preventive effect of the Topping-off technique from ASDe progression and ASDi development.

Conclusion

The results of our study have led us to infer that the use of DRC as the Topping-off technique cannot prevent radiological degenerative changes, whereas it has been associated with better clinical outcomes in terms of preventing patients with preoperative degenerative changes at the adjacent level from developing symptomatic ASDi.

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