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Original Article

Impact of the Dynesys dynamic stabilization system on the fixation-adjacent intervertebral discs

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Abstract: Objective: The aim of this study was to analyze the impact of the Dynesys system on fixation-adjacent intervertebral discs. Methods: Thirty six patients with lumbar degeneration diseases, who were treated with the Dynesys neutralization system (DNS) and posterior fusion method, were followed up for an average of two years. The Oswestry disability index (ODI) score was applied to analyze the clinical effects. The Woodend classification and apparent diffusion coefficient (ADC) scores of Magnetic Resonance Imaging (MRI) were used to analyze the imaging performance. Results: The results of the 24 to 48-month follow-up examination revealed that the ODI scores of the patients improved significantly ($P<0.05$). The ADC value of the Dynesys group on the final follow-up was statistically significant compared with the preoperative ADC value ($P<0.05$), and the final ADC scores were significantly different between the two groups ($P<0.05$). Conclusions: Dynamic stabilization of posterior lumbar vertebrae with the Dynesys system may prevent and delay the degeneration of intervertebral discs at the fixed segments.

Keywords: Intervertebral disc degeneration, magnetic resonance imaging, dynamic fixation, internal fixation

Introduction

Degenerative lumbar disease is a commonly occurring orthopedic disease. Although spinal fusion surgery of the segments causing pain is the most important clinical surgical intervention used currently [1], the incidence of postoperative complications is high. Due to the biomechanical changes induced by the surgery, the lumbus becomes unstable and the motility of the postoperative lumbus is limited; this may be followed by pseudoarthritis, which accelerates the degeneration of the adjacent segments and even the recurrence of preoperative symptoms [2]. The exact cause of adjacent-segment degeneration is still not very clear, but the changes in adjacent-segment small joints, excessive activity, as well as increased intradiscal stress, may be some of the important reasons [3, 4].

To prevent these problems, the concept of a new non-fusion dynamic stabilization system (DNS) was proposed and applied clinically for the treatment of lumbar degenerative diseases in 1994. In an in vitro study, Schnake et al. [5] confirmed that the Dynesys system could effectively stabilize the unstable segments and may replace the spinal fusion method.

Consequently, the use of the DNS system has become more widespread in recent years. Studies of the DNS system, both domestic and international, have mostly concentrated on the fixed segments, while few studies analyzed the impacts on the adjacent segments. Hence, the current retrospective study used the follow-up data from 36 patients who were treated with the DNS for the treatment of lumbar degenerative diseases. The purpose of the study was to summarize and analyze the MRI follow-up results from the early and mid-postoperative stages, aiming to analyze whether the degeneration of adjacent segments, relative to the fusion, was reduced after the lumbar dynamic stabilization surgery.

Materials and methods

General information

A total of 36 lumbar disease patients treated in our department were included in the study, who comprised 16 men and 20 women. The age of

Table 1. Basic information of the 2 groups

Surgical method	Gender (cases)		Mean age (years)	Follow-up time (months)	Fused segments		
	Male	Female			$L_{4,5}$	L_5S_1	L_4/L5/S_1
Dynesys	7	5	58.3±13.5	28.7±5.3	4	5	3
PLIF	9	15	61.4±15.2	30.1±6.8	9	10	5

Table 2. Woodend classification

Classification	MRI images of lumbar disc	Height of lumbar disc
1	Even high signals	Normal
2	High signals or uneven high signals	Reduced by 10%
3	Uneven high signals or low signals	Reduced by 10%-50%
4	Low signals	Reduced more than 50%

the patients ranged from 43 to 68 years with the mean age of 59 years and disease duration ranging from 1-8 years. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee. Written informed consent was obtained from all participants. Among these patients, 18 cases were lumbar disc herniation, 10 cases were lumbar spondylolisthesis, and 8 cases were lumbar spinal stenosis. The patients were randomly divided into two groups: the dynamic fixation group (12 patients) and the posterior lumbar interbody fusion (PLIF) group (24 patients). The preoperative clinical manifestation in all the patients was lower back pain, accompanied with soreness in the waist and hip. Unilateral or bilateral lower limb radiating pain was found in 26 patients, among who 16 patients presented with intermittent claudication. Patients with diseases such as vertebral and accessory fractures, cancer, and others were excluded. All the patients underwent routine normal- and lateral-side X-ray, as well as flexion and extension dynamic X-ray, computerized tomography (CT), magnetic resonance imaging (MRI), and diffusion-weighted imaging (DWI). The basic characteristics of the two groups are shown in **Table 1**.

Treatment

1) Position and exposure: The patient was laid in the prone position, and a straight incision was made at the middle segment of the lumbus to fully reveal the spinous process, lamina, and zygapophysial joint; vertebral pedicle screws were implanted at the vertebral pedicles of the relevant segments. 2) Decompression: In the fusion group, laminectomy was performed on both sides of 8 diseased vertebrae to remove the proliferated fibrous connective tissues, callus, thickened flava ligaments, and medial small processus articularis, and to unobstruct the nerve root canal and remove the nucleus pulposus, so that the dural sac and nerve root could undergo thorough decompression. Patients in the dynamic fixation group underwent partial laminectomy, with the bilateral small processus articularis of the diseased vertebra preserved; the proliferated and compressed tissues were removed to effect decompression of the nerve root. 3) The interbody fixation implantation: In the fusion group, the intervertebral space was distracted for the implantation of the interbody fusion at the diseased segment, followed by autologous bone graft fusion. The DNS (Zimmer (Shanghai) Medical International trade Co., Ltd) was used in the dynamic fixation group. 4) Postoperative process and rehabilitation: The patients were placed on conventional negative pressure drainage and antibiotics post-operatively to prevent infection. The patients were allowed to be ambulatory with a brace one to two weeks after the operation.

Clinical evaluation methods

The Oswestry disability index score (ODI) was used for clinical functional assessment during the preoperative and postoperative follow-up.

MRI analysis

Before and after surgery, as well as at final follow-up, 1.5T MRI (Siemens (Beijing) China) was used for lumbar scanning; the scan sequences included the sagittal T1WI, T2WI, axial T2WI, and DWI. An experienced radiologist and an orthopedic surgeon reviewed the MRI results independently. Lumbar disc degeneration was assessed by using the Woodend classification (**Table 2**) and ADC [6].

Determination of ADC [4]: The DWI was performed by an experienced radiologist. With the median sagittal plane as the detection plane,

Table 3. Comparison of ODI scores of the 3 groups before and after the surgery ($\bar{x}\pm s$)

ODI	Before the surgery (points)	Postoperative 6th month (points)	Postoperative 12th month (points)	Final time (points)
Dynesys	60.46±10.25	21.18±6.46*	16.07±4.82*	10.83±5.68*
PLIF	58.29±9.83	23.16±6.17*	18.43±5.66*	12.28±3.37*
P	>0.05	>0.05	>0.05	>0.05

Note: Compared with the preoperative, *P<0.05.

Table 4. MRI average Woodend classifications of the segment above the fixed disc before the surgery and on the final follow up (the Dynesys group, n=12)

	Final follow up				
Before	1	2	3	4	Summary
1	2	1	0	0	3
2	1	7	0	0	8
3	1	0	0	0	1
4	0	0	0	0	0
Summary	4	8	0	0	12

Table 5. MRI average Woodend classifications of the segment above the fixed disc before the surgery and on the final follow up (the PLIF group, n=24)

	Final follow up				
Before	1	2	3	4	Summary
1	2	0	0	0	2
2	0	7	6	03	16
3	0	2	1	2	5
4	0	1	0	0	1
Summary	2	10	7	5	24

Table 6. Comparisons of ADC values of the 2 groups before the surgery and on the final follow up ($\bar{x}\pm s$, $\times 10^{-3}$ mm^2/s)

T2	Before the surgery	Final follow up
Dynesys	1.05±0.28	1.20±0.24*
PLIF	1.17±0.40	0.93±0.27*
P	>0.05	<0.05

Note: Compared with the preoperative, *P<0.05.

approximately 100 mm of the central part of the nucleus pulposus, which was one segment above the fixed segment, was selected for the measurement of ADC. Each patient was tested three times and the average value was used in the final analysis.

Statistical analysis

All the imaging data were independently analyzed by an experienced radiologist and an orthopedic surgeon in a double-blinded manner. Then they would gather for discussion, and the resultant data were analyzed using a Student's t test. SPSS13.0 was used for the pair wise comparison of the ODI and ADC values obtained before and after the surgery. P<0.05 was considered to be statistically significant.

Results

The 36 patients were followed up for 24 to 48 months. The postoperative 6 months, 12 months, and final follow-up ODI scores were recorded, and the lumbar spine MRI was reviewed in the final review.

Assessment of clinical efficacy

The ODI scores of the two groups at the 3 follow-ups exhibited significant improvement compared with those before the surgery (P<0.05), while there were no significant differences between the two groups (P>0.05) (**Table 3**).

MRI imaging evaluation

The detailed Woodend classification scores before surgery and on the final follow-up MRI are shown in **Tables 4** and **5** for comparison. In the Dynesys group, the final follow-up revealed that one case of grade III degenerative disc had degenerated to grade II, one case of grade II degenerative disc had degenerated to grade I, while no significant changes were found in the other cases. In the PLIF group, the final follow-up showed 6 cases that degenerated from grade II to 5 cases of grade III and 1 case of grade IV, and 3 cases of grade III that degenerated to grade IV.

Among the 36 intervertebral discs, the Dynesys group had 2 cases that exhibited artifacts so that the ADC values could not be measured; hence, the ADC values of 34 discs were measured before the surgery and at final follow up (**Table 6**). The ADC values of the Dynesys group were higher than those before the surgery and

the difference was statistically significant ($P<0.05$); while the ADC values of the PLIF group were lower than those before the surgery and the difference was statistically significant ($P<0.05$). The ADC values of the two groups showed no significant difference before the surgery ($P>0.05$), while those at final follow-up were significantly different ($P<0.05$).

Discussion

Adjacent segment degeneration after spinal fusion surgery can be due to many factors including patient factors and iatrogenic factors [7-9]. It is generally considered that the increased load on the adjacent segments after fusion surgery may be the main biomechanical factor that causes adjacent segment degeneration [10-15]. The principle behind the design of Dynesys is to relieve the added stress load on the degenerative disc and zygapophysial joints while retaining their normal activities, thus avoiding the concentration of too much stress in adjacent segments. In recent years, the application of DNS has achieved good clinical results [16]. Hoppe et al. [17] reviewed 39 cases of lumbar degeneration who were treated with the DNS since 1994. At the end of follow-up, 89% of the patients with lower back pain and 86% of the patients with leg pain saw improvements. Patient satisfaction with the procedure was high and only 6 patients had to undergo a repeat operation due to the degeneration of adjacent segments. However, other clinical studies showed that the role of Dynesys in relieving the degeneration of adjacent segments is not clear. Ghiselli et al. analyzed 32 patients who underwent the Dynesys dynamic fixation and the 2-year follow-up results showed that the adjacent segments continued to degenerate after the Dynesys fixation; hence, the author suggested that this kind of degeneration might be part of the disease process, since even without significant contact with the interbody fixation, the Dynesys dynamic fixation system did not eliminate the degeneration of the adjacent segments. Our results showed that the ODI scores of the patients exhibited significant improvement and the patients were satisfied with the operation. DNS was an effective method in the treatment of lumbar vertebral degeneration; we hypothesize that degeneration is the natural development of the disease and segments that were originally degenerated would be more likely to continue to degenerate [18-22].

Common methods used to evaluate the degeneration of adjacent segments mainly include X-ray and MRI, etc., and we chose MRI due to higher sensitivity. The Woodend classification system, which uses the intervertebral disc height and nucleus pulposus signal as the classification standards, has been globally recognized as effective. Furthermore, since the ADC values of the intervertebral discs can be used to detect the water content of the intervertebral discs, they can be indirect measures of the degree of disc degeneration. According to the DWI-determined ADC values, the higher the water content inside the intervertebral disc, the faster the molecular diffusion and the higher the ADC values would be; and vice versa. DWI is the only non-invasive technique that measures water diffusion in vivo and reflects the structural features of organs through the motion state of water molecules. Hence, DWI is potentially useful in early diagnosis where the non-invasive evaluation of treatment effects and prognosis judgment of disc degeneration are important [23, 24]. Kumar et al. [8] followed 32 patients with lumbar disease who were treated with the DNS for 2 years using MRI. According to the Woodend grading results of the degeneration of adjacent segments, it was found that the DNS could reduce the degeneration of adjacent segments. In this study, we used the Woodend classification and analyzed two groups with a total of 36 intervertebral discs; the results revealed that there was no significant degeneration in the DNS group after the surgery till the end of follow-up and improvements were observed in some patients, while the intervertebral discs in the fixation group exhibited significant degeneration compared with the preoperative situation and that at the last follow-up. The ADC values of the two groups had no statistically significant preoperative difference ($P>0.05$), while the final follow-up revealed statistically significant differences in the ADC values between the two groups ($P<0.05$). The last ADC of the Dynesys group was higher than the preoperative value, indicating that the postoperative water content was higher than the preoperative one and disc degeneration was alleviated or reversed; whereas, the ADC values at final follow-up in the internal fixation group were lower than

those before the surgery, indicating that the post-operative water content was lower than the preoperative one and disc degeneration had progressed.

DWI is the only non-invasive technique that measures the diffusion of water molecules in the living tissues and reflects the structural features of tissues through detecting the movement of water molecules inside the tissues. Our study shows that the pathogenesis of disc degeneration might be associated with the decreased rate of molecular diffusion. DWI may have potential applications in the early diagnosis of disc degeneration, non-invasive evaluation of treatment effect, and prognosis judgment because of its ability to quantitatively assess the extent of diffusion of water molecules in living tissues [17]. The intervertebral discs with different degrees of degeneration had significantly different levels of nucleus pulposus water content and annulus integrities; the higher the degree of degeneration, the lower the water content would be, and the integrity of the annulus would be much more easily damaged. In DWI, higher disc water content indicates faster molecular diffusion and higher ADC values; conversely, lower disc water content indicates slower molecular diffusion and lower ADC values. The purpose of this study was to quantitatively evaluate the disc status of the adjacent intervertebral discs through DWI. There was no statistically significant difference in the ADC values of the two groups preoperatively ($P>0.05$), while those at the final follow-up exhibited statistically significant difference between the two groups ($P<0.05$). The ADC value at final follow-up in the Dynesys group was higher than the preoperative value, indicating that the water content of the nucleus pulposus was higher than the postoperative water content, and the degree of disc degeneration was alleviated or even reversed; while in the PLIF group, the ADC value at final follow-up was lower than the preoperative value, indicating that the water content of the nucleus pulposus was lower than the postoperative water content, and the degree of disc degeneration was aggravated.

Therefore, from the perspective of MRI imaging, our results show that the posterior lumbar Dynesys dynamic stabilization system may prevent and delay the degeneration of the intervertebral discs of dynamically fixed segments. The limitations of the study include the small number of patients and short follow-up period; hence, further studies with larger numbers of patients and longer periods of follow-up are warranted.

Conclusions

The DNS has been widely used in the treatment of lumbar degenerative diseases. From the perspective of MRI imaging results, we can conclude that the Dynesys dynamic stabilization system may prevent and delay the degeneration of the intervertebral discs of fixed segments.

Disclosure of conflict of interest

None.

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