Posterior dynamic stabilization system (Dynesys) with interbody fusion for treating two-segment lumbar degenerative disc disease

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KEYWORDS

dynamic neutralization stabilization system; fusion surgery; hybrid surgery; nonfusion surgery; spine

Summary Purpose: To assess clinical outcomes and kinematic changes in bridged and adjacent segments after hybrid stabilization by interbody fusion. Background: Conventional management for multilevel lumbar degenerative disc disease is limited to either fusion or nonfusion surgery alone. The severity of degeneration and instability in multilevel lumbar degenerative disc disease vary widely. Therefore, surgical treatment for multilevel lumbar degenerative disc disease is usually performed in a single stage by either fusion, nonfusion, or a hybrid technique. To the best of our knowledge, no kinematic study of a Dynesys fusion—nonfusion technique has yet been reported. Methods: This study analyzed 28 patients who had undergone posterior lumbar interbody fusion with posterior dynamic stabilization fixation for spondylolisthesis with adjacent level...
1. Introduction

Lumbar fusion is a commonly indicated surgical procedure for treating multisegmental degenerative disc disease or spondylolisthesis. The goals are to maintain or restore stability of the spine. However, spinal fusion reportedly accelerates degenerative change in the caudal or cranial adjacent segments due to both the altered biomechanics of the spine and the compensated hypermobility of the adjacent segment. Biomechanical changes in the spine can overload facet joints, which in turn increases stress and mobility in the adjacent segment. Adjacent segment degeneration or disease (ASD) may then occur. \(^1\),\(^2\) Follow-up studies of patients 2–5 years after undergoing lumbar fusion show that the incidence of radiographical ASD after the procedure varies from 6% to 46.8%. \(^3\)–\(^9\) However, some follow-up studies performed 1–5 years after the procedure show a lower incidence of symptomatic ASD (2.3–30.3%). \(^6\),\(^10\)–\(^14\)

Multisegmental degenerative lumbar disc disease is conventionally managed by either fusion or nonfusion surgery alone. Patients with multisegmental degenerative lumbar disc disease show a wide variation in degeneration and instability. In each stage of surgery for multisegmental degenerative lumbar disc disease, different surgical techniques may be required, including fusion, nonfusion, or hybrid techniques.

The dynamic stabilization system (Dynesys), which uses a nonfusion pedicle screw stabilization system, was developed to overcome the corroboratory disadvantages of conventional fusion surgery for multisegmental lumbar degenerative disc disease. Dynesys is designed to permit restricted movement across a functional spinal unit under normal or near-normal loading. The system is also designed to preserve intersegment kinematics, to reduce loading of the facet joints, and to reduce degeneration of adjacent segments. \(^15\)–\(^19\) However, the indications for fusion or nonfusion surgery in patients with lumbar spondylolisthesis and adjacent segment stenosis are controversial. Bertagnoli et al. \(^20\) first proposed different combinations of nonfusion and fusion constructs for treating lumbar degenerative disc disease at each level. Schwarzenbach et al. \(^21\) reported good clinical outcomes of the hybrid fusion—nonfusion technique for treating multilevel lumbar degenerative disc disease.

The recently developed Dynesys hybrid stabilization technique combines interbody cage fusion and stabilization in a segment-by-segment treatment of lumbar spondylolisthesis and adjacent segment stenosis.

To the best of our knowledge, no kinematic study of a Dynesys fusion—nonfusion hybrid technique has yet been reported. Therefore, this study presents the clinical and kinematic results achieved by a Dynesys hybrid technique in a segment-by-segment treatment of multisegmental lumbar degenerative disc diseases.

2. Materials and methods

2.1. Clinical characteristics of patient population

Twenty-eight patients underwent posterior lumbar interbody fusion and posterior dynamic stabilization fixation for lumbar spondylolisthesis and adjacent segment stenosis between May 2007 and June 2008. All patients included in this study were followed up for at least 2 years. The clinical characteristics of all patients were retrospectively reviewed. The 28 patients included 10 males and 18 females with an age range from 40 to 75 years (mean age: 60 years). The mean follow-up period was 32.7 months (range: 24–37 months).

2.2. Surgical technique in Dynesys with fusion

All patients underwent posterior lumbar interbody fusion by Dynesys fixation in a prone position with midline excision. Laminctomy, foraminectomy, and discectomy were performed to decompress the neural component. After decompression, posterior lumbar interbody cage fusion was performed in the spondylolisthesis segment, and Dynesys was performed to stabilize the two segments with disc stenosis between May 2007 and June 2008. All patients were followed up for at least 2 years. Clinical characteristics were then retrospectively reviewed. The visual analog scale (VAS) was used to score both lower limb pain and back pain. Patient functioning was evaluated using the Oswestry Disability Index (ODI).

Results: Both VAS and ODI significantly improved during the follow-up period (p < 0.001). Global motion significantly decreased after surgery (p = 0.027). Analyses of adjacent segment motion after surgery showed significant increases in neutral lordotic curves (p < 0.001) and in range of motion (ROM; p < 0.001). Whereas the adjacent segment tended to show hypermobility, ROM measured in the bridged segment before and after surgery did not change significantly.

Conclusion: Dynesys stabilization with interbody fusion improves clinical outcomes, enables successful interbody fusion, and maintains the ROM in the bridged segment. However, the procedure may decrease ROM in the global segment and cause hypermobility in the adjacent segment. Further in vivo or in vitro experiments are needed to optimize spacer length and cord tension when performing this procedure.

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All pedicle screws were inserted by free-hand technique and their locations were confirmed by X-ray. The spacer length was measured by the pedicle distance gauge between the two adjacent screw heads. The cord was assembled under a compression of 300 N. After the fused segment was assembled, the spacer and cord were set up using the standard procedure. All the procedures were performed by a single surgeon (Dr S.-L.H.).

2.3. Clinical outcome

Before surgery and at the final follow-up, clinical outcomes were assessed with the Oswestry Disability Index (ODI)\textsuperscript{22} and the visual analog scale (VAS).\textsuperscript{23} The VAS was used to evaluate both lower limb and back pain scores. The ODI was used to evaluate the quality of life of the patients.

2.4. Radiographic outcome

2.4.1. Global segment motion

Static radiographs (anteroposterior and lateral standing) and dynamic radiographs (flexion and extension views) of the lumbar spine were taken in all patients before and after surgery (Figs. 1 and 2). Global lordotic angles and segmental lordotic angles in the operated segments and adjacent segments were measured by the Cobb method. Global lordotic angles were measured from the upper end plate of T12 to the upper end plate of the sacrum (Fig. 3; $\alpha$ is the angle of global segment). After measuring the angles, the range of motion (ROM) in the global segment was calculated.

2.4.2. Intersegmental motion

The Cobb’s angles in those postoperative, bridge and adjacent segments were measured between the upper end plates of the corresponding segments (Fig. 4; $\beta$ is the Cobb’s angle of adjacent segment; $\gamma$ is the Cobb’s angle of bridge segment; $\delta$ is the Cobb’s angle of fusion segment). After measuring the angles, the ROM was calculated in the operated segments and adjacent segments.

2.5. Statistical analysis

Preoperative and postoperative VAS scores and ODI scores were compared by paired $t$ tests. Preoperative and postoperative global motion and intersegmental motion were also compared using paired $t$ tests. A $p < 0.05$ was considered statistically significant. The analysis was performed using SPSS 17.0 statistical software package (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Clinical outcomes

Table 1 compares function measurements taken before and after the surgery. The comparisons showed significant
improvements in back VAS scores (7.48 ± 1.35 and 2.00 ± 1.07 before and after surgery, respectively; p < 0.001); leg VAS scores (7.59 ± 0.82 and 1.52 ± 0.57 before and after surgery, respectively; p < 0.001); and ODI scores (52.1 ± 3.1% and 11.1 ± 5.6% before and after surgery, respectively; p < 0.001). All functional outcome measurements showed significant improvements after surgery.

3.2. Radiographic outcome

3.2.1. Global segment motion

Table 2 shows the global kinematic change in the global segment after surgery. Although the static lordotic angle was decreased (27.1° ± 8.6°) postoperatively, the difference from preoperative lordotic angles did not reach statistical significance (p = 0.263). The surgical treatment did not significantly change the flexion lordotic angle (20.9° ± 11.4° before surgery and 22.6° ± 9.3° after surgery; p = 0.220). However, the surgery significantly improved the extension lordotic angle (33.7° ± 13.5° before surgery and 31.3° ± 10.6° after surgery; p = 0.001). The ROM in the global segment significantly decreased from 12.9° ± 9.0° before surgery to 8.7° ± 7.6° after surgery (p = 0.010). The ROM from neutral to flexion in the global segments also significantly decreased (p = 0.003). However, the surgery did not significantly change the ROM from neutral to extension in the global segments (p = 0.437).

3.2.2. Adjacent segment motion

Table 3 shows the segmental kinematic change in the adjacent segment after surgery. The neutral lordotic angle in adjacent segment significantly increased from 8.3° ± 5.3° preoperatively to 11.5° ± 6.5° postoperatively (p < 0.001). The flexion lordotic angle in the adjacent segment increased from 4.7° ± 6.1° before surgery to 6.6° ± 6.8° after surgery, but the difference was not statistically significant (p = 0.091). The extension lordotic angle in the adjacent segment decreased from 31.7° ± 10.6° before surgery to 30.6° ± 10.7° after surgery (p = 0.037). The ROM measurement for the global lumbar segment showed significant decreases after surgery, possibly due to the postoperative decrease in ROM from flexion to extension.

Table 1 Comparison of functional outcomes before and after Dynesys fixation in combination with fusion technique.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative status</th>
<th>Postoperative status</th>
<th>p</th>
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<tbody>
<tr>
<td>VAS/back pain</td>
<td>7.48 ± 1.35</td>
<td>2.00 ± 1.07</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VAS/leg pain</td>
<td>7.59 ± 0.82</td>
<td>1.52 ± 0.57</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ODI 2.0(%)</td>
<td>52.1 ± 3.1</td>
<td>11.1 ± 5.6</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

ODI = Oswestry Disability Index; VAS = visual analog scale.
angle in the adjacent segment significantly increased from $10.2^\circ \pm 5.0^\circ$ preoperatively to $14.9^\circ \pm 6.6^\circ$ postoperatively ($p < 0.001$). The ROM in the adjacent segment significantly increased from $5.6^\circ \pm 4.3^\circ$ preoperatively to $8.3^\circ \pm 4.2^\circ$ postoperatively ($p = 0.014$). The surgery also significantly increased ROM from neutral to extension in the adjacent segment ($p = 0.041$). However, the surgery did not significantly affect ROM from neutral to flexion in the adjacent segment ($p = 0.091$). The neutral lordotic angle in the adjacent segment was significantly increased after surgery. The significant increase in ROM may have resulted from the ROM increase in ROM from neutral to extension.

3.2.3. Bridged segment motion
Table 4 shows the segmental kinematic change in the bridged segment after surgery. Surgery did not significantly change the neutral lordotic angle in the bridged segment ($7.2^\circ \pm 4.3^\circ$ before surgery and $7.8^\circ \pm 5.8^\circ$ after surgery; $p = 0.587$). Besides, surgery did not significantly change the flexion lordotic angle in the bridged segment ($5.4^\circ \pm 7.0^\circ$ before surgery and $6.3^\circ \pm 5.6^\circ$ after surgery; $p = 0.766$) and did not significantly change the extension lordotic angle in the bridged segment ($8.3^\circ \pm 6.7^\circ$ before surgery and $8.7^\circ \pm 5.4^\circ$ after surgery; $p = 0.551$). In short, the surgery did not significantly affect the bridged segment.

4. Discussion
Dynesys stabilization with interbody fusion is an alternative treatment for multisegmental lumbar disc degeneration with spondylolisthesis. Segment-by-segment surgical treatments with and without fusion have been developed for multisegmental lumbar disease. Fusion surgery is usually performed in highly unstable segments or in discs with advanced intervertebral degeneration. In this study, nonfusion Dynesys surgery was performed in cases of mild disc degeneration and in cases of unstable motion segments in degenerated intervertebral discs. The Dynesys hybrid stabilization was originally developed by Schwarzenbach et al. to treat multisegmental degenerative disc disease by combining fusion and nonfusion techniques. This study analyzed 80 lumbar segments treated in 31 patients over a mean follow-up period of 39 months (range: 24–90 months). Evaluations of functional outcomes by ODI and VAS showed significant improvements. Solid fusion was achieved in 100% of the segments. Out of 31 patients, three (9.7%) patients, including two with ASD, required further surgical intervention. The surgical results suggest that segment-by-segment treatment by Dynesys combined with interbody fusion is technically feasible, safe, and effective for surgical treatment of multisegmental degenerative disc disease. The patient follow-up also showed good clinical outcomes after hybrid surgery. Although good clinical outcomes of the hybrid technique for treating multisegmental degenerative disc disease have been reported previously, no studies have reported the kinematic behavior of hybrid constructs. Kumar et al. evaluated radiographic change in the intervertebral disc after dynamic stabilization by Dynesys. Of the 32 patients in their study, 12 underwent Dynesys stabilization with fusion, and none showed significant change in the adjacent discs.

Use of dynamic stabilization with interbody fusion (hybrid construct) after microsurgery decompression in multisegmental lumbar disease has several potential benefits: first, the hybrid constructs enable stabilization of the fused segment by the tension band effect. The tension band effect on the spacer and cord is known to decrease motion in the fused segment and to improve the fusion

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Comparison of the global kinematic change before and after surgery in the global segment.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
</tr>
<tr>
<td>Neutral lordosis</td>
<td>$28.6^\circ \pm 11.0^\circ$</td>
</tr>
<tr>
<td>Flexion lordosis</td>
<td>$20.9^\circ \pm 11.4^\circ$</td>
</tr>
<tr>
<td>Extension lordosis</td>
<td>$33.7^\circ \pm 13.5^\circ$</td>
</tr>
<tr>
<td>ROM from neutral to flexion</td>
<td>$7.7^\circ \pm 6.5^\circ$</td>
</tr>
<tr>
<td>ROM from neutral to extension</td>
<td>$5.1^\circ \pm 5.6^\circ$</td>
</tr>
<tr>
<td>ROM of the global segment</td>
<td>$12.9^\circ \pm 9.0^\circ$</td>
</tr>
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</table>

ROM = range of motion.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Comparison of the segmental kinematic change before and after surgery in the adjacent segment.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
</tr>
<tr>
<td>Adjacent neutral lordosis</td>
<td>$8.3^\circ \pm 5.3^\circ$</td>
</tr>
<tr>
<td>Adjacent flexion lordosis</td>
<td>$4.7^\circ \pm 6.1^\circ$</td>
</tr>
<tr>
<td>Adjacent extension lordosis</td>
<td>$10.2^\circ \pm 5.0^\circ$</td>
</tr>
<tr>
<td>ROM from neutral to flexion</td>
<td>$3.6^\circ \pm 3.0^\circ$</td>
</tr>
<tr>
<td>ROM from neutral to extension</td>
<td>$2.0^\circ \pm 2.7^\circ$</td>
</tr>
<tr>
<td>ROM of the adjacent segment</td>
<td>$5.6^\circ \pm 4.3^\circ$</td>
</tr>
</tbody>
</table>

ROM = range of motion.
Table 4  Comparison of the segmental kinematic change before and after surgery in the bridged segment.

<table>
<thead>
<tr>
<th>Preoperative</th>
<th>Postoperative</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridged neutral lordosis</td>
<td>7.2 ± 4.3°</td>
<td>7.8 ± 5.8°</td>
</tr>
<tr>
<td>Bridged flexion lordosis</td>
<td>5.4 ± 7.0°</td>
<td>6.3 ± 5.6°</td>
</tr>
<tr>
<td>Bridged extension lordosis</td>
<td>8.3 ± 6.7°</td>
<td>8.7 ± 5.4°</td>
</tr>
</tbody>
</table>

rate. As in Schwarzenbach et al., the current study obtained a 100% fusion rate in the fused segment. Furthermore, dynamic neutralization decreased the load on the facet joint and protected the facet joint in the bridged segment. A comparison of motion in the bridged segment before and after surgery showed no significant difference.

Motion in the nonfusion segment (bridged segment) was preserved to provide a transition zone between the fused segment and motion segment and to protect the adjacent segment. Theoretically, the transition zone should reduce degeneration of the adjacent segment. However, analyses of the adjacent segment in our patients showed hypermobility. Previous in vitro experiments showed that the kinematic effects obtained by Dynesys were similar to those observed in fusion surgery. A possible explanation is that Dynesys provided intersegmental stability by functioning similar to a rigid-rod-fixation system and caused hypermobility of the adjacent motion segments. The rigidity of Dynesys is known to reduce its protective effect on the adjacent segment.

Our results also revealed decreased ROM in the global segment and increased ROM in the adjacent segments. The kinematic changes in the hybrid construct are apparently similar to those that occur in a Dynesys stabilization procedure. One concern about the Dynesys hybrid construct applied here is its high rigidity. Although the effects of spacer length and cord tension on segmental flexibility and rigidity are still debated in the literature, we favor that determining these essential parameters before performing Dynesys improves outcomes of the procedure. Niosi et al reported that spacer length affects compression of posterior elements, that is, the facet load increases as spacer length decreases. Niosi et al also showed that a longer spacer length increases ROM and the overall size of the motion pattern. Although evidence of the precise effects of spacer length and cord tension is not yet convincing, a longer spacer and a lower tension cord may increase the flexibility of Dynesys. Based on our clinical experience, the difference in spacer length and cord tension between the fused segment and bridged segment should be set to obtain optimal flexibility of the bridged segment. This study used a long spacer length and a low cord tension in the bridged segment. By contrast, a short spacer length and a high cord tension were used in the fused segment to create a rigid segment, which improved the fusion rate.

5. Conclusion

A hybrid technique combining Dynesys stabilization and interbody fusion can achieve successful interbody fusion, and maintain ROM in the bridged segment and thus improve clinical outcomes. However, it may decrease ROM in the global segment and cause hypermobility in the adjacent segment. Further in vivo and in vitro experiments are needed to optimize spacer length and cord tension when performing this procedure.

References


