The Dynesys Lumbar Spinal Stabilization System

A Preliminary Report on Positional Magnetic Resonance Imaging Findings

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Study Design. We present the positional magnetic resonance imaging findings of a prospective case series of patients undergoing surgery with the Dynesys spinal stabilization device (Zimmer, Inc., Warsaw, IN).

Objective. To explore the biomechanical impact of the Dynesys device in vivo.

Summary of Background Data. Spinal fusion surgery is widely used for painful degenerative conditions of the lumbar spine that have not responded to conservative measures. It often produces good outcomes but can be associated with adjacent segment hypermobility that may lead to further degeneration and pain. Previous cadaveric biomechanical studies claim that the Dynesys Dynamic Spinal Stabilization System allows some lumbar movement, behaving similar to a normal spine in extension but similar to rigid fixation in flexion.

Methods. Twenty-four patients with dominant low back pain, with or without leg pain, were treated with the Dynesys. All patients underwent positional magnetic resonance imaging before surgery and 9 months after surgery. Measurements were made to assess the differences at the operated level, adjacent level, and whole lumbar spine.

Results. There was a statistically significant reduction in flexion-extension range of movement of both the whole lumbar spine by 13.37° (P = 0.002) and at the instrumented segments by 4.08° (P < 0.001) following surgery. There was an insignificant reduction in range of movement at the level above instrumentation (P = 0.807). Mean anterior disc height at the instrumented level reduced by 0.7 mm following insertion of the Dynesys (P < 0.001). Mean anterior disc height reduced by 0.3 mm (P = 0.453). In a neutral posture, the Dynesys had no significant impact on lordosis or inclination of operated or adjacent levels. Contrary to cadaveric study findings, the Dynesys appears to restrict extension more than flexion with respect to a neutral posture.

Conclusions. In vivo, the Dynesys Stabilization System allows movement at the instrumented level, albeit reduced, with no significant increased mobility at the adjacent segments. There was reduction of the anterior disc height without a significant increase of the posterior disc height.

Key words: degenerative lumbar disc disease, Dynesys, adjacent segment hypermobility, positional magnetic resonance imaging, dynamic posterior stabilization.

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Chronic back pain due to intervertebral disc degeneration that has not responded to conservative measures has traditionally been treated by fusion of the affected levels. For several years, research has focused on the development of successful adjuncts and alternatives to spinal fusion.

Despite many reported advantages with spinal fusion surgery, it is not without risk, and many problems remain. These include pseudarthrosis, donor site pain, infection, instrumentation failure, and nonunion. Another potential problem following spinal fusion surgery is increased movement at adjacent motion segments.1-14 It is possible that the hypermobile level above a fusion may be at increased risk for disc degeneration and is cited as a cause for revision surgery in patients who have previously undergone spinal fusion.2-5

Techniques that preserve motion are being proposed as successors to fusion in the management of degenerative conditions of the lumbar spine. Dynamic posterior stabilization, however, is not a new concept. The first such system was the Graf ligamentoplasty, which used knitted Dacron bands (INVISTA, Wichita, KS) looped around the ends of pedicle screws, essentially locking the facet joints in extension.6 Using this technique, the regional lordosis was preserved, and a degree of flexibility of the lumbar spine was maintained. Although positive short-term results were obtained in well-selected, young patients,7-10 longer term follow-up results were not as good.10 The device appeared to compress the posterior anulus, decreasing the size of the exit foramina and spinal canal.7,11 Other devices have since been developed, however, the Dynesys (Zimmer, Inc., Warsaw, IN) is 1 of the more popular systems available.

Dr. Gilles Dubois introduced the Dynamic Neutralization System (Dynesys) for the spine, and it was first used in France in 1994.12 The system uses transpedicular screws, fabricated polyethylene-terephthalate cords, and spacers made from polycarbonate urethane (Figure 1). The pedicle screws are linked with a cord and spacers instead of rigid rods, as employed by spinal fusion procedures. Theoretically, stabilization of the posterior elements in this manner off-loads the facet joints, as well as the posterior disc,13 and allows some segmental move-
The length of spacer used determines the degree of distraction or compression placed on each motion segment.

In this study, the Dynesys was used alone or in combination with nerve root decompression for the treatment of patients whose dominant complaint was low back pain. The changes in motion of the lumbar spine in the weight-bearing posture were measured before and following insertion of the device using positional magnetic resonance imaging (MRI).

Our study aims to evaluate the biomechanical impact of the Dynesys on the lumbar spine, operated and adjacent levels in vivo.

**Materials and Methods**

This is a prospective evaluation of a consecutive series of patients undergoing surgery using the Dynesys. All patients suffering with dominant, chronic low back pain, with or without radicular pain, were evaluated clinically by stress diskography and MRI using the Woodend Classification.

The Dynesys was used in all patients with MRI measured disc heights greater than 40% of normal who experienced concordant pain on stress diskography. If this group of patients also experienced discordant pain in degenerate grade II or III discs at adjacent levels on MRI, then the Dynesys was applied to these levels as well.

Patients with previous spinal surgery, chemonucleolysis, severe osteoporosis, evidence of tumor, metastases, infection, and pregnancy at the time of surgery were excluded.

In this study, 24 consecutive patients with dominant low back pain, with or without leg pain, were treated with the Dynesys. One spinal surgeon (D.W.) performed or directly supervised every procedure. Operations were done through 1 midline or 2 parallel Wiltse type incisions. When decompression was also carried out, a midline skin incision was made for the decompression. The skin was then retracted laterally, and the implant was inserted via 2 parallel Wiltse fascial incisions.

It is recommended that when inserted, depending on the distance between the pedicle screw heads, which could range from 15 to 30 mm, 1-3 mm be added to the spacer length, causing some distraction to off-load the facet joints. A tensioning device on the cord then acts on the screw heads, compressing the spacer by approximately 1 mm during insertion of the locking screws. Small variations in the angle of the screws in relation to the vertical axis resulted in differences in the lengths of the spacers on each side in some cases. Patients were permitted to mobilize as able from their first postoperative day, and were given advice to avoid lifting, bending, and twisting motions.

Patients underwent positional MRI before surgery and at 9 months after surgery. The 0.6-T “upright” positional MRI scanner (FONAR Corp., Melville, NY) has an open configuration designed to image any part of the patient’s body in different postures. The purpose of this study was not to provide a comparison between MRI and radiograph images.

There are advantages of using positional MRI over plain flexion and extension radiographs. It eliminates radiation exposure, ensures that a midsagittal image is used for measurements, and is, therefore, more accurate. Its only disadvantage is that for patients, it takes longer to perform than radiographs. Patients were asked to flex or extend, as we would have done for flexion-extension radiographs.

The MRI scans were performed in standing, left and right lateral flexion, and sitting in neutral, forward flexion, and extension. The scans were done sufficiently late in the day to ensure that there was no effect from being recumbent overnight and the disc hydration had stabilized to the upright posture.

Patients were asked to flex and extend as far as they could comfortably during scanning periods. When a flexed or extended position was established, support bars were placed to ensure that movement during scanning periods was minimal. A lumbar bolster was used to aid extension. These measures ensured that full flexion and extension were maintained during each 3-minute scanning period. Not all patients were scanned in every posture due to early differences in the scan protocol. As...
a result of this, only 17 patients were scanned in a neutral sitting posture.

Measurements of the L1–S1 angle and individual intervertebral endplate angles were made from midline sagittal T2 images, in neutral, full flexion, and extension. Measurements of the intervertebral disc heights at the operated levels and adjacent levels were made from midline sagittal images in a neutral sitting posture. From these data, we were able to measure the difference in lumbar spine flexion-extension motion, movement of the operated and adjacent segments, and the changes in the anterior and posterior disc height at all relevant levels. Measurements of lateral bending were made from coronal images in full left and right lateral flexion.

The Osiris 4.19 software (University of Geneva, Switzerland) was used to make the measurements. To measure endplate angles, lines were drawn across each endplate, ensuring that osteophytes were not used as reference points. The angle subtended between the 2 lines was thus measured and deemed to represent the individual endplate angle (Figure 2).

When measuring the L1–S1 angle, lines were drawn in a similar fashion to those mentioned above (i.e., from the superior endplate of L1 to superior endplate of S1) (Figure 2). Disc height was assessed by measurement of lines drawn at the most anterior and posterior endplate of L1 to superior endplate of S1) (Figure 2). The measured vertebral height should not be influenced by surgery. Lines were drawn that best fit across the superior and inferior endplates of the L3 vertebra, and then the distance between them, in the anterior edge, was calculated.

One trained observer made the measurements. Intraobserver error calculations were made between 2 sets of measurements of the same 5 preoperative scans several months apart. Interobserver error was calculated based on a second trained observer’s interpretation of 12 patients measurements, which represents 50% of the total data. All data were analyzed using the SPSS 12.0.1 statistics package (SPSS, Inc., Chicago, IL). Wilcoxon signed ranks tests were used to compare mean findings and calculate significance values. Pearson correlation calculations were done to measure intraobserver and interobserver error. A value of $P < 0.05$ was accepted as clinically significant.

## Results

### MRI Registration Error

The preoperative mean value of the anterior height of the vertebral body of L3 was 25.13 mm and postoperative mean 25.24 mm, a difference of 0.11 mm. The Spearman value was 0.997 ($P < 0.001$), demonstrating that there was an extremely small MRI registration error.

### Error

Intraobserver and interobserver error calculations were done and are illustrated in Tables 1 and 2. Both tables contain correlation coefficients and significance levels, and demonstrate good intraobserver and interobserver agreement.

### Population

Twenty-four consecutive patients were selected for inclusion. There were 10 female and 14 male patients, with a mean age of 43.8 years (range 25–59). The total number of operated levels was 47. The distribution of operated levels is illustrated in Table 3. Eight procedures were performed at 1 level (33%), 10 at 2 levels (42%), 5 at 3 levels (21%), and 1 4-level procedure was performed (4%). Eight patients did not have surgery at L5–S1, therefore it was

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**Table 1. Intraobserver Error Calculations in a Group of 5 Patients’ Preoperative Scans Using Pearson’s Correlation Coefficient (r Value)**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>$P$</th>
<th>$r$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endplate flexion angle at instrumented level</td>
<td>0.003</td>
<td>0.806</td>
</tr>
<tr>
<td>Endplate extension angle at instrumented level</td>
<td>&lt;0.001</td>
<td>0.963</td>
</tr>
<tr>
<td>Total lumbar flexion</td>
<td>0.003</td>
<td>0.981</td>
</tr>
<tr>
<td>Total lumbar extension</td>
<td>0.001</td>
<td>0.989</td>
</tr>
<tr>
<td>Anterior disc height instrumented level</td>
<td>0.018</td>
<td>0.692</td>
</tr>
<tr>
<td>Posterior disc height instrumented level</td>
<td>0.006</td>
<td>0.764</td>
</tr>
</tbody>
</table>

In all cases, good agreement was reached.

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**Table 2. Interobserver Error Calculations in Preoperative and Postoperative Scans in 12 Patients Using Pearson’s Correlation Coefficient (r Value)**

<table>
<thead>
<tr>
<th>Preoperative</th>
<th>$P$</th>
<th>$r$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endplate flexion adjacent level</td>
<td>0.002</td>
<td>0.805</td>
</tr>
<tr>
<td>Endplate extension adjacent level</td>
<td>&lt;0.001</td>
<td>0.976</td>
</tr>
<tr>
<td>Endplate range adjacent level</td>
<td>&lt;0.001</td>
<td>0.855</td>
</tr>
<tr>
<td>Endplate flexion instrumented level</td>
<td>&lt;0.001</td>
<td>0.930</td>
</tr>
<tr>
<td>Endplate extension instrumented level</td>
<td>&lt;0.001</td>
<td>0.919</td>
</tr>
<tr>
<td>Endplate range instrumented level</td>
<td>&lt;0.001</td>
<td>0.821</td>
</tr>
<tr>
<td>Anterior disc height instrumented level</td>
<td>&lt;0.001</td>
<td>0.806</td>
</tr>
<tr>
<td>Posterior disc height instrumented level</td>
<td>&lt;0.001</td>
<td>0.692</td>
</tr>
<tr>
<td>Endplate flexion adjacent level</td>
<td>0.001</td>
<td>0.989</td>
</tr>
<tr>
<td>Endplate extension adjacent level</td>
<td>&lt;0.001</td>
<td>0.859</td>
</tr>
<tr>
<td>Endplate range adjacent level</td>
<td>0.002</td>
<td>0.826</td>
</tr>
<tr>
<td>Endplate flexion instrumented level</td>
<td>&lt;0.001</td>
<td>0.955</td>
</tr>
<tr>
<td>Endplate extension instrumented level</td>
<td>&lt;0.001</td>
<td>0.787</td>
</tr>
<tr>
<td>Endplate range instrumented level</td>
<td>&lt;0.001</td>
<td>0.915</td>
</tr>
<tr>
<td>Endplate extension instrumented level</td>
<td>&lt;0.001</td>
<td>0.779</td>
</tr>
<tr>
<td>Endplate range instrumented level</td>
<td>0.021</td>
<td>0.486</td>
</tr>
<tr>
<td>Anterior disc height instrumented level</td>
<td>&lt;0.001</td>
<td>0.817</td>
</tr>
<tr>
<td>Posterior disc height instrumented level</td>
<td>&lt;0.001</td>
<td>0.859</td>
</tr>
</tbody>
</table>

In all cases, good agreement was reached.
possible to obtain information on adjacent segment motion caudal to instrumentation in these patients.

**Total Lumbar Motion (L1–S1)**
The mean preoperative range of movement of the lumbar spine (L1–S1 flexion-extension angle) was 37.79° (range 22°–75°). Postoperatively, this was decreased to 24.42°, a reduction of 13.37° ($P < 0.002$).

**Instrumented Segment Motion**
At the instrumented levels, the mean segmental range of movement preoperatively (flexion-extension) was 5.70°. Following the operation, this was reduced to 1.62°, a difference of 4.08° ($P < 0.002$). Lateral bending ROM at the operated segment reduced from 3.02° preoperatively to 0.20° postoperatively (difference 2.82°; $P < 0.002$).

**Adjacent Segment Motion—Above Instrumentation**
The mean segmental range of movement in the sagittal plane at the level above the instrumentation preoperatively was 7.67°, and the value after surgery was 7.25°, a reduction of 0.42° ($P = 0.807$). The degree of lateral motion reduced from 5.87° to 3.65° following insertion of the Dynesys. This represents a difference of 2.22° ($P = 0.002$).

**Adjacent Segment Motion—Caudal to Instrumentation**
Eight patients’ data were analyzed. The mean preoperative ROM at the caudal level before the Dynesys was 4.25°. This had reduced to 2.25° after surgery, a difference of 2.00° ($P = 0.404$). Lateral motion at this level reduced by 0.87°, from 2.75° to 1.88° after insertion of the Dynesys ($P = 0.585$).

**Effect of the Dynesys in Neutral Posture**
Seventeen patients with 34 operated levels were imaged in a neutral sitting posture, as well as in flexion and extension. The mean preoperative and postoperative angles of lordosis (L1–S1 angle) in a neutral posture were 24.88° and 26.29°, respectively ($P = 0.297$). The mean endplate angle of the operated segment in a neutral posture was 1.85° before surgery and 1.21° after surgery ($P = 0.694$). The endplate angle at the cranial adjacent segment decreased from 2.06° to 1.82° after surgery ($P = 0.622$) and at the caudal motion segment increased from 1.00° to 2.86° ($P = 0.176$).

**Flexion-Extension With Respect to Neutral**
Figure 6 displays the relative degrees of flexion and extension achievable with respect to the neutral posture at operated and adjacent levels, as well as the lumbar spine as a whole. These values were calculated as the mean of the difference between angles measured in neutral and flexion, and neutral and extension. At the operated segment, postoperative extension is restricted more than flexion, whereas at the adjacent levels, the converse is true.

**Disc Height**
Measured disc heights in a neutral sitting position before and following surgery are illustrated in Table 4.

**Discussion**
Our results have shown that in vivo at 9 months after surgery, the Dynesys significantly reduces overall lumbar motion by 35.4% and instrumented segmental motion by 71.6%. It also reduces cranial adjacent segment motion by an insignificant 5.5%. It does not significantly reduce lordosis in a neutral posture nor does it have any significant impact on the inclination of the operated or adjacent segments in this posture.
There is a graded increase in the preoperative segmental range of movement with an increasing number of segments involved. This may be coincidental due to the small numbers in each group. Similarly, there appears to be considerable variation in the effect on postoperative motion according to the number of operated levels, which may also be a consequence of the differences in screw position and spacer length from level to level and side to side.

Schmoelz et al\textsuperscript{14} performed in vitro biomechanical analysis of the behavior of the Dynesys on cadaveric human spinal motion segments. Their results suggested that the Dynesys significantly restricts flexion to a similar degree to internal fixation, while permitting extension similar to a normal spine. Evaluation of adjacent segment motion revealed no increase in ROM in either fusion or stabilization groups.\textsuperscript{14}

Our findings, in fact, suggest the opposite regarding the Dynesys’ impact on the operated segment. We have demonstrated in vivo that the Dynesys restricts extension rather than flexion. We believe that this is due to increased spacer length, distracting posterior to axis of movement, tilting the segment into flexion, and restricting extension. In the cadaveric study, however, the spacer length was the same as measured between the screw heads so that when extended, the segment was in fact “blocked” in extension.

Table 4. Disc Heights at Relevant Levels Before and Following Surgery

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADH–Operated</td>
<td>9.1</td>
<td>8.4</td>
<td>-0.7</td>
<td>0.027</td>
</tr>
<tr>
<td>PDH–Operated</td>
<td>8.2</td>
<td>7.9</td>
<td>-0.3</td>
<td>0.453</td>
</tr>
<tr>
<td>ADH–Level above</td>
<td>9.4</td>
<td>9.2</td>
<td>-0.2</td>
<td>0.375</td>
</tr>
<tr>
<td>PDH–Level above</td>
<td>8.2</td>
<td>8.5</td>
<td>+0.3</td>
<td>0.574</td>
</tr>
<tr>
<td>ADH–Level below</td>
<td>10.1</td>
<td>10.6</td>
<td>+0.5</td>
<td>0.357</td>
</tr>
<tr>
<td>PDH–Level below</td>
<td>8.9</td>
<td>8.9</td>
<td>0.0</td>
<td>1.000</td>
</tr>
</tbody>
</table>

ADH indicates anterior disc height; PDH, posterior disc height.

Their findings\textsuperscript{14} at adjacent segments, both cranial and caudal, are in keeping with our results. Lateral bend results in our cohort also show a significant reduction in adjacent segment motion. We believe that this is the result of the screw head’s proximity to the inferior facet joint of the adjacent level, restricting lateral motion at this level.

One advantage of the Dynesys is in its perceived ability to reduce adjacent segment hypermobility.\textsuperscript{14} Studies have shown that in long-term follow-up, the rate of the symptomatic degeneration at the level adjacent to a fusion may be as high as 36.1\%\textsuperscript{17,18} and may be even higher in interbody cage fusion-type procedures.\textsuperscript{19,20} The “abnormal” motion at the level above instrumentation is thought by some to lead to other segmental changes such as facet arthritis, spinal stenosis, and degenerative spondylolisthesis, but further evidence is needed.\textsuperscript{18,21}

Not all hold the theory of adjacent segment hypermobility and degeneration. According to Penta et al,\textsuperscript{4} the fusion itself may not be entirely responsible for postoperative segmental degeneration. Certain individuals may have a genetic predisposition for the development of degenerative spondylolisthesis. Other groups, however, assert that the degenerative changes at the first level above fusion are equal to those at subsequent levels, concluding that there is no statistical difference in the radiologic changes between the fusion group and an age-matched nonsurgical control group.\textsuperscript{22} In studies involving thoracolumbar fusions, there was no significant increase in movement at the level below the fusion, suggesting that only levels above instrumentation were at risk.\textsuperscript{23}

The Dynesys stabilizes the segment in a slightly distracted state, acting posterior to the center of movement of the normal disc.\textsuperscript{15} Although analysis in the neutral posture before and following surgery suggests an insignificant trend of the operated segment to become less lordotic by an average of 0.64\°, a small but significant reduction in anterior disc height of 0.7 mm was seen. Cadaver studies undertaken by Akamura et al\textsuperscript{24} demonstrated that fusion in a hyperlordotic position signifi-
cantly increases adjacent segment motion, however, with the Dynesys, this does not appear to be the case. Such studies must always be interpreted with caution due to the fact that the cadaveric spine is passive, and many functioning structures have been removed. Our measurements have been carried out in vivo and, as such, we believe are more valuable.

There are few studies that report the clinical outcomes following the Dynesys, and these vary considerably. The device is used in these studies in a variety of conditions, including degenerative disc disease, spinal stenosis, failed back surgery, degenerative spondylothesis, following nucleotomy and extradural tumor.12,25–27

Limitations

The measurements made from the coronal images of the left and right flexion presented some difficulties. The MRI taken through L4–5 and especially L5–S1, where the lordosis is most pronounced, does not delineate the intervertebral endplates well, making measurement difficult. Also, although the pelvis was stabilized, there was trunk rotation in some patients while performing a lateral bend. Similarly, the degree to which patients flex and extend varies according to the degree of pain experienced at the time of examination. There will, therefore, be some slight inaccuracies in these data as a result.

Conclusions

Overall, this study shows that the Dynesys spinal stabilization system allows a reduced range of movement at the instrumented levels with an associated slight reduction in adjacent segment motion. It does not significantly reduce lordosis in a neutral posture nor does it have any significant impact on the inclination of the operated or adjacent segments in this posture, however, it does appear to reduce anterior disc height at the instrumented level after insertion.

Key Points

- The Dynesys is a semirigid posterior spinal stabilization device.
- Positional MRI is a useful tool in assessing the impact of spinal implants in vivo.
- The Dynesys appears to reduce overall spinal and individual motion segment movement.
- The Dynesys appears to eliminate adjacent segment hypermobility.

References