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# Anterior Lumbar Interbody Fusion for Degenerative Discogenic Low Back Pain

## *Evaluation of L4–S1 Fusion*

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**Abstract:** The treatment of degenerative discogenic pain is controversial, and anterior lumbar fusion for the treatment of degenerative discogenic low back pain has also been a controversial topic for over a generation.

The aim of this systematic review was to evaluate the outcome of different anterior lumbar fusion levels for degenerative discogenic low back pain.

In this study, we performed a clinical outcome subgroup analysis. The outcomes of 84 consecutive patients who underwent anterior lumbar interbody fusion from 2004 to 2009 were reviewed. The operative time, intraoperative blood loss, hospital stay, Oswestry Disability Index (ODI), visual analog scale (VAS) results, and complication rate were recorded separately.

Medical indications were degenerative disc disease (73.8%), post-discectomy disc disease (16.1%), and disc herniation (9.5%). Patients with severe spondylolysis or disc degeneration, with more than 3 or multilevel lesions, were excluded.

The mean operative time was  $124.5 \pm 10.9$  min (range 51–248 min), the mean intraoperative blood loss was  $242.1 \pm 27.7$  mL (range 50–2700 mL), the mean hospital stay was  $3.9 \pm 1.1$  days (range 3–6 days), the mean preoperative VAS score was  $7.5 \pm 1.4$ , and the mean preoperative ODI score was  $60.0 \pm 5.7$ . At the 1-year follow-up, the mean postoperative VAS score was  $3.3 \pm 1.3$  and the mean postoperative ODI score was  $13.6 \pm 3.4$  ( $P < 0.05$ ). L4–L5 disc fusion led to better clinical results than 2-level L4–L5/L5–S1 disc fusion. Additionally, the 2-level fusion of L4–L5/L5–S1 had better clinical results than the L5–S1 disc fusion at both the 1 and 2-year postoperative follow-ups regarding the VAS score and the ODI score. The rate of complications was more frequent in the 2-level L4–L5/L5–S1 group (27.3%) (group C) than in the L4–L5 group (9.1%) (group A) and the L5–S1 group (12.5%) (group B). There was no difference between the L4–L5 group (9.1%) and the L5–S1 group (12.5%). A venous tear occurred during surgery and was successfully repaired in 6 of the 84 patients. Also, out of the 84 patients, 6 were found with pseudarthrosis during the follow-up, and

these patients underwent a spinal fusion with instrumentation, with a posterior approach after a mean of 1 year. The complications secondary to the surgical approach were persistent abdominal pain (1/84, 1.2%) and wound dehiscence (1/84, 1.2%).

Anterior lumbar interbody fusion for L4–L5 had better clinical results than the 2-segmental L4–L5/L5–S1 disc fusion, and the 2-segmental L4–L5/L5–S1 disc fusion had better clinical results than the L5–S1 disc fusion. Also, the 2-segmental L4–L5/L5–S1 disc fusion had a higher complication rate (27.3%), but there was no difference between the L4–L5 group (9.1%) and the L5–S1 group (12.5%).

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**Abbreviations:** ALIF = anterior lumbar interbody fusion, DDLBP = degenerative discogenic low back pain, LBP = low back pain, ODI = Oswestry Disability Index, TDR = total disc replacement, VAS = visual analog scale.

## INTRODUCTION

Low back pain was identified as “the leading” debilitating condition worldwide and represents a tremendous socioeconomic and health care burden. Although not always synonymous with each other, disc degeneration is regarded as one of the determinants related to the development of low back pain.<sup>1</sup> The treatment of degenerative discogenic pain is also controversial. There are no prospective randomized controlled studies demonstrating that surgery is useful for degenerative discogenic pain. Most spine surgeons agree that discectomy alone usually is not helpful for degenerative discogenic pain. However, several longitudinal series strongly suggest that total disc replacement (TDR) relieves symptoms.

Dynamic techniques and fusion are useful for degenerative discogenic pain.<sup>2</sup> Lumbar TDR is indicated in the management of degenerative discogenic back pain without facet arthritis. However, many patients with degenerative discogenic back pain have facet arthritis, segmental instability, and loss of intervertebral height. More than 95% of patients with potential surgical indications are likely to have a contraindication for lumbar TDR.<sup>3,4</sup> Recently, lumbar TDR was shown to be superior to fusion in cases presenting with lower adjacent-level degeneration.<sup>5</sup> Dynamic techniques for spinal stabilization have also been described. The newer designs including the dynamic neutralization system for the spine (Dynesys Dynamic Stabilization System; Zimmer, Warsaw, IN) attempt to reduce motion equally in flexion and extension. There is no support for the superiority of dynamic stabilization compared to typical arthrodesis. The use of lumbar fusion has wider indications. Therefore, fusion will continue to be an essential part of the spine surgeon’s armamentarium for the foreseeable future. Patients with posterior fusion often complain of residual discomfort and pain associated with screw irritation, which makes

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surgeons believe that anterior interbody fusion may be a better option.<sup>6</sup> Anterior lumbar interbody fusion (ALIF) removes this structure and replaces it with a bone transplant for the treatment of degenerative discogenic low back pain (DDLBP).<sup>7</sup> ALIF has advantages compared to posterior lumbar interbody fusion because the anterior approach permits more extensive disc removal, avoids scarring of the neural canal, and preserves the posterior elements.<sup>8</sup>

The purpose of our study was to demonstrate the effectiveness of surgical therapy using ALIF. Additionally, we evaluated the outcome of different anterior lumbar fusion levels in patients with DDLBP.

## MATERIALS AND METHODS

We reviewed the records of 84 consecutive patients who underwent ALIF from January 2004 to December 2009, with institutional review board approval of the authors' institution. We included patients with severe and therapy-resistant DDLBP. The patients had more than 2 years of existing pain without ongoing psychiatric illness. All the patients failed to respond to conservative treatment including physical therapy and injections. The patients with severe spondylolysis or disc degeneration with more than 3 or multilevel lesions were excluded from this study. Degenerative changes (spondylosis) were shown on plain radiographs, computed tomography (CT) scan, and/or magnetic resonance imaging (MRI). There were no specific radiologic findings such as isthmic spondylolisthesis, spinal stenosis, new or old fractures, infection, inflammation, or neoplasm. There were no previous spine surgeries reported in the patients' past medical histories, except for the successful removal of a herniated disc more than 2 years before entering this study.

The diagnosis of DDLBP was confirmed by demonstrating a "black disc" on MRI along with the provocation of pain after discography.<sup>9,10</sup> We confirmed the diagnosis of DDLBP by discography and discoblock (intradiscal injection) using lidocaine.

All patients were identified by reviewing the "Electronic Patient Records." All clinical notes including inpatient operative and discharge summaries were reviewed for a minimum of 2 years. The presence of preoperative severe DDLBP was assessed by the treating surgeon as emanating from L4–L5, L5–S1, or both. The DDLBP was not accompanied by any dominant leg pain component. The preoperative and postoperative clinical outcomes were evaluated using the visual analog scale (VAS) and the Oswestry Disability Index (ODI) for back and leg pain. VAS is one of the most commonly used measures of pain intensity in pain research,<sup>11–14</sup> with a scale graduation of 0 to 10 cm (0 cm, minimal pain; 10 cm, maximal pain). ODI includes 10 sections of questions that evaluate the activities of daily living, such as sitting, walking, standing, sleeping, and so on, which can be drastically influenced by LBP.<sup>15</sup> The total score ranges from 0 to 100, with 0 representing no disability and 100 representing maximum disability. The VAS and ODI scores before surgery, and 1 and 2 years after surgery were recorded and compared.

If patients had persistent low back pain, then a CT scan was performed 1 year after surgery. We evaluated bone union by both radiograph and CT.

## Discography or Discoblock for the Diagnosis of Degenerative Discogenic LBP

Discography and discoblock were performed with a standard posterolateral approach using a 22-gauge needle. A

discoblock is a modification of discography in which a local anesthetic such as lidocaine is infused with the contrast agent into the disc to enhance the diagnostic capability of the procedure. A contrast agent (range 1.0–1.5 mL) was injected into each disc until severe pain was provoked or contrast medium leaked from the disc into the spinal canal. If a leak occurred, then 0.5 mL of 1% lidocaine was injected into the disc. We confirmed the diagnosis of degenerative discogenic pain if the pain was provoked when using discography and decreased when using discoblock. We localized the degenerative discogenic pain level and performed surgery on 1 or 2 levels.

## Surgery

Eighty-four patients diagnosed with discogenic pain underwent anterior discectomy and internal fixation. The patients were placed in the supine position, and a standard retroperitoneal approach was performed with ligation of the segmental vessels. The great vessels were mobilized to expose the anterior surface and lateral borders of the disc space. The midpoint of the disc space was identified with radiographic markers and fluoroscopy. An incision was made in the anterior portion of the annulus to remove the anterior longitudinal ligament and the anterolateral borders of the annulus fibrosus. Under direct visualization, the entire contents of the disc space, including the nucleus pulposus and the cartilaginous endplates, were removed. Interbody fusion was then performed using implants with packed cancellous autograft harvested from the adjacent vertebral body. The donor sites were either packed with allograft material from the Synthes Corporation and then fixed with screws, or interbody fusion was performed using femoral ring allografts. The implants were fixed with two 25-mm screws. Powdered Gelfoam was used for hemostasis along with the plate and screws for fixation. We did not perform additional posterior fusion.

## Statistical Analysis

The data were compared using independent-sample *t* tests. The differences between various age groups were analyzed using 1-way analysis of variance (ANOVA). When the ANOVA found a significant difference among the groups, a post hoc pairwise multiple comparison procedure (Tukey test) was performed to test all pairs of groups. The differences with a  $P < 0.05$  were considered statistically significant.

## RESULTS

Our study included 84 patients (43 men and 41 women), with a mean age of  $41.5 \pm 6.9$  years (range 21–68 years). The mean duration of follow-up was 35 months (range 25–83 months). The fused level was L4–L5 in 11 (13.1%) patients (group A), L5–S1 in 40 (47.6%) patients (group B), and L4–L5/L5–S1 in 33 (39.3%) patients (group C). The medical indications were degenerative disc disease (DDD) in 74% of the patients, postdiscectomy disc disease in 16%, and disc herniation in 9.5% (Table 1).

Fourteen patients had previous successful spine surgery with removal of a herniated disc more than 2 years before this study. The mean operative time was  $124.5 \pm 10.9$  min (range 51–248 min). There was a significant difference between the L4–L5 (group A), L5–S1 (group B), and the L4–L5/L5–S1 (group C) groups ( $P < 0.05$ ). However, there was no significant difference between groups A and B ( $P > 0.05$ ). The mean intraoperative blood loss was  $242.1 \pm 27.7$  mL (range 50–2700 mL). There was a significant difference among the 3

**TABLE 1.** Demographic, Preoperative, and Postoperative Data in the Overall Population

	Total (n = 84)	L4–L5 (n = 11) Group A	L5–S1 (n = 40) Group B	L4–L5/L5–S1 (n = 33) Group C
<b>Etiology</b>				
Degenerative	62 (73.8%)	6 (54.5%)	29 (72.5%)	27 (81.8%)
Postdiscectomy	14 (16.8%)	2 (18.2%)	6 (15.0%)	6 (18.2%)
Disc herniation	8 (9.5%)	3 (27.3%)	5 (12.5%)	0 (0%)
<b>Instrumentation</b>				
Plate	61	10	24	27
Cage + screws	23	1	16	6
Sex	M: 43, F: 41	M: 5, F: 6	M: 17, F: 23	M: 21, F: 12
Symptom duration, mean (range), y*	1.9 (0.6–9)	1.8 (0.6–7)	1.5 (0.9–8)	2.1(0.7–9)
Age (years)*	41.5	39.2	41.1	42.9
Operative time (min)†	124.5 ± 10.9	112.1 ± 9.7	107.9 ± 8.9	148.6 ± 15.9
Intraoperative blood loss (mL)†	242.1 ± 27.7	247.3 ± 26.8	191.4 ± 19.7	338.2 ± 32.3
Hospitalization stay (d)*	3.9 ± 1.1	3.8 ± 1.2	3.4 ± 1.09	4.1 ± 1.4
Preop VAS*	7.5 ± 1.4	7.6 ± 1.5	7.5 ± 1.1	7.6 ± 1.8
Preop ODI	60.0 ± 5.7	57.3 ± 4.2	60.1 ± 6.3	60.1 ± 7.7
Subjective satisfaction	65 (77.4%)	9 (81.8%)	30 (75%)	26 (78.8%)

ODI = Oswestry Disability Index, preop = preoperative, VAS = visual analog scale.

\* Statistically no significant difference among the 3 groups ( $P > 0.05$ ).

† There was statistically significant difference among the 3 groups ( $P < 0.05$ ).

groups for blood loss ( $P < 0.05$ ). The mean hospital stay was  $3.9 \pm 1.1$  days (range 3–6 days), and there was no difference among the 3 groups ( $P > 0.05$ ). (Table 1)

The mean preoperative VAS and ODI scores were  $7.5 \pm 1.4$  (7–10) and  $60.0 \pm 5.7$  (46–76), respectively. The mean postoperative VAS and ODI scores were  $3.3 \pm 1.3$  and  $13.6 \pm 3.4$  ( $P < 0.05$ ), respectively. There was a significant improvement in the lumbar pain and function (Table 2). However, there was no significant improvement in lumbar pain and lumbar function when comparing the 1-year with the 2-year postoperative follow-up in terms of VAS and ODI scores among the 3 groups (Table 2; Fig. 1). Our study confirmed that L4–L5 disc fusion led to better clinical results than 2-level L4–L5/L5–S1 disc fusion. Interestingly, the 2-level fusion of L4–L5/L5–S1 had better clinical results than the L5–S1 disc fusion at both the 1 and 2-year postoperative follow-ups regarding the VAS

and ODI scores (Table 2). However, there was no statistically significant difference.

The overall complication rate was 16.7%, and complications were more frequent in the 2-level L4–L5/L5–S1 group (27.3%) than in the L4–L5 (9.1%) and the L5–S1 groups (12.5%) ( $P > 0.05$ ). There was no difference between the L4–L5 group (9.1%) and the L5–S1 group (12.5%;  $P > 0.05$ ). In 6 out of the 84 patients, a venous tear occurred during instrumentation. In 2 patients, the tear was located in the inferior vena cava. In the other 4 patients, the tear was located in the internal iliac vein and was successfully repaired. In 6 patients, we noted evidence of pseudarthrosis at 1 year after surgery and these patients underwent a spinal fusion with instrumentation from the posterior approach (Fig. 2). The complications secondary to the surgical approach were persistent abdominal pain (1/84, 1.2%) and wound dehiscence (1/84, 1.2%) (Table 3). A revision surgery was necessary

**TABLE 2.** Visual Analog Scale and Oswestry Disability Index in the 3 Groups

	Total (n = 84)	L4–L5 (n = 11) Group A	L5–S1 (n = 40) Group B	L4–L5/L5–S1 (n = 33) Group C
<b>VAS</b>				
Preop	7.5 ± 1.4	7.6 ± 1.5	7.5 ± 1.1	7.6 ± 1.8
Postop 1 y*	3.3 ± 1.3	2.9 ± 1.2	3.7 ± 1.1	3.0 ± 1.5
Postop 2 y*	2.1 ± 1.0	1.9 ± 1.0	2.4 ± 0.9	2.1 ± 1.1
<b>ODI</b>				
Preop	60.0 ± 5.7	57.3 ± 4.2	60.1 ± 6.3	60.1 ± 7.7
Postop 1 y*	13.6 ± 3.4	9.9 ± 2.7	15.6 ± 3.3	13.3 ± 3.5
Postop 2 y*	6.2 ± 2.9	5.6 ± 2.1	7.3 ± 3.1	6.1 ± 3.8

There was statistically no significant improvement of lumbar pain, and lumbar function between postoperative follow-up 1-year and follow-up 2-year VAS score and ODI score among the 3 groups ( $P > 0.05$ ). ODI = Oswestry Disability Index, postop = postoperative, preop = preoperative, VAS = visual analog scale.

\* There was no statistically significant difference among the 3 groups ( $P < 0.05$ ).



**FIGURE 1.** Anteroposterior (A) and lateral (B) standard X-rays of L4–L5/L5–S1 fusion. After 1-year (C, D) and 2-year FU (E, F), the 26-year-old man had a significant improvement in ODI (from 57 preop to 6 at 2-year FU), and VAS (from 8 preop to 1 at 2-year FU). FU = follow-up, ODI = Oswestry Disability Index, VAS = visual analog scale.

in 7 patients. Of these 7 patients, 6 patients had persistent low back pain caused by pseudarthrosis and underwent a spinal fusion with instrumentation from the posterior approach after 1 year. The other 1 patient had malpositioning of the implant. Nineteen patients (22.9%) were dissatisfied with surgery after discography and discoblock, and reported continued low back pain radiating to both hips and into the buttocks. Three of these patients had a permanent spinal cord stimulator implant and obtained some relief. Additionally, 4 patients were workers' compensation cases, 4 patients were overweight, 3 patients had mild to moderate distress, 3 patients attributed low back pain to their occupation where they performed repetitive twisting from the waist at work, and 2 patients attributed low back pain to excessive physical therapy.

## DISCUSSION

Lumbar fusion for the treatment of DDLBP has been a controversial topic for over a generation.<sup>16</sup> For every author championing its use, there is another author critical of the practice. The debate over surgical management of LBP will

likely continue, especially with advancements in the use of artificial disc technology. The source of DDLBP should be confirmed or localized, and is not necessarily determined by all physicians using provocative discography.<sup>9</sup> However, the reliability of discography has been controversial. Carragee EJ<sup>17</sup> reported that pain relief after injection of a small amount of bupivacaine into the painful disc was a more useful tool for the diagnosis of DDLBP than discography. In our study, we used this technique for diagnosing DDLBP.

Degenerative discogenic pain may go unrecognized as a potential cause of failed back surgery syndrome. The degenerative discogenic pain can occur at the level of prior surgery or at other motion segments.<sup>18</sup> The pain arises from the annulus of the disc itself rather than from impingement on neural elements.<sup>19</sup> The outer annulus and the posterior longitudinal ligament are known to be richly innervated by nociceptive fibers.<sup>20</sup> It is generally accepted that mechanical deformation or inflammation can stimulate these nociceptors. In addition, it is hypothesized that a damaged nucleus may produce inflammatory chemicals that stimulate or sensitize nociceptors.<sup>21</sup> Weatherley et al<sup>22</sup> reported 5 patients with solid posterolateral



**FIGURE 2.** Anteroposterior (A) and lateral (B) standard X-rays of L4–L5/L5–S1 fusion. One year later, the 59-year-old woman complained of persistent low back pain because of postoperative pseudarthrosis in L4–L5/L5–S1 fusion (C, D). She underwent a subsequent revision surgery (E, F) and had a significant improvement in ODI (from 60 preop to 7 at 2-year FU), and VAS (from 8 preop to 2 at 1-year FU). FU = follow-up, ODI = Oswestry Disability Index, VAS = visual analog scale.

fusions that had persistent disabling back pain and concordant pain on discography at a level within the fusion. Four of these patients underwent anterior lumbar fusion and had complete pain relief. Previous biomechanical studies have shown that an interbody fusion is stiffer and diminishes intervertebral motion

more than a posterolateral fusion.<sup>23</sup> Other investigators advocate an inflammatory etiology for degenerative discogenic pain and suggest that excision of the disc during interbody fusion may yield a better outcome than posterolateral fusion.<sup>24</sup> The posterior interbody fusion techniques require longer operative times and have higher complication rates. Stauffer and Coventry<sup>25</sup> reported a 40% nonunion rate with the posterior procedure. The posterior interbody fusion requires exposure of the spinal canal and may cause epineural scar formation leading to chronic radiculopathy.<sup>26</sup> Thus, posterior fusion patients often have residual discomfort associated with “screw irritation.” Importantly, the degree of acceptable arthritis and a method of distinguishing between the different sources of LBP need to be clarified. There are patients who continue to have pain after a posterolateral lumbar fusion. Wetzel and LaRocca<sup>26</sup> reported a series of failed posterior lumbar interbody fusions and suggested that the increased risks of posterior lumbar interbody fusions may not be warranted in the management of degenerative discogenic back pain.

**TABLE 3.** Preoperative and Postoperative Complications in the 3 Groups L4–L5 (A), L5–S1 (B), and L4–L5/L5–S1 (C)

	Total	L4–L5	L5–S1	L4–L5/L5–S1
Iliac vein injury	6	1	1	4
Pseudoarthrosis	6		3	3
Malposition of the instrumentation	1			1
Persistent abdominal pain	1		1	
Wound dehiscence	1			1

Svante and Tycho<sup>27</sup> reported better results after TDR at 1 year than for posterior fusion. Disc arthroplasty or total lumbar disc replacement (TLDR) can be effective against degenerative discogenic pain. However, there are many contraindications considered by surgeons. These general contraindications include the following: osteoporosis or other osteopathy that reduces load-bearing capacity of the vertebral body endplate (increased risk of implant slipping), vertebral fracture, acute or chronic spondylodiscitis, severe obesity, foreign body sensitivity to implant materials, drug abuse or alcoholism, psychosocial factors, disc herniation with predominant radicular symptoms or signs of cauda equine compression, posterior element pathology (such as Fujiwara III–IV° facet spondylarthrosis, spinal canal stenosis, postlaminectomy), translational forward instability (isthmic or degenerative listhesis), and severe end-plate irregularities (eg, large Schmorl nodes).<sup>28</sup> In our study, there were 14 patients with a history of previous discectomy, 11 patients with degenerative listhesis, 5 patients with III° facet spondylarthrosis, and 7 patients with severe end-plate irregularities. Due to the high risk of complications and the lack of long-term prospective randomized clinical studies, some authors claim that “it is difficult to defend the choice of a TLDR for chronic DDLBP.”<sup>29</sup> The prevalence of diagnoses currently considered to be contraindications to TDR is high in patients with degenerative discogenic pain. Therefore, anterior instrumented fusion will continue to be an essential part of the spine surgeon’s armamentarium for the foreseeable future.

Among the 84 patients in this study, the subjective satisfaction rate was 81.8% (9/11) in the single-level L4–L5 group, 78.8% (30/40) in the double-level L4–L5 and L5–S1 groups, and 75% (26/33) in the single-level L5–S1 group (Table 1). There was a significant improvement in ODI and VAS scores 2 years after anterior instrumented fusion (Table 2). Despite a large number of studies certifying the efficacy of anterior instrumented fusion, there is still a need for studies investigating predictive outcomes in TLDR.<sup>26</sup> Our study confirms that L4–L5 disc fusion has better clinical results than the 2-level L4–L5/L5–S1 disc fusion, and the 2-level L4–L5/L5–S1 disc fusion had better clinical results than the L5–S1 disc fusion (Table 2). However, there was no statistically significant difference (Table 2). This might be explained by the fact that lumbosacral junction is a volatile and delicate region of the lumbar spine. The same clinical outcome parameters were observed when TDR was performed in this region.<sup>30</sup> With a mean hospitalization of less than 5 days, our patients showed a mean return to ambulation in approximately 5 days. However, there was no significant difference between anterior fusion at the single-level L4–L5 or the 2-level L4–L5/L5–S1 or L5–S1 (Table 1). Our patients wore a soft lumbar brace for a period of 6–8 weeks postoperatively.

The complication rates in anterior instrumented fusion are variable in the literature. Anterior abdominal surgery complications include the following: paralytic ileum, small intestine occlusion, retrograde ejaculation secondary to sympathetic hypogastric plexus injury, caval vein injury, left iliac vein lesion, left urethral lesion, left iliac vein thrombosis, pelvic phlebitis, infection, deep hematoma, and laparocoele.<sup>31</sup> In our group of patients, the mean complication rate was 16.7%. The 2-level L4–L5/L5–S1 disc fusion group had a higher complication rate (27.3%), and this was significantly different from the L4–L5 and the L5–S1 groups ( $P < 0.05$ ). There was no significant difference between the L4–L5 group and the L5–S1 group (12.5%;  $P > 0.05$ ). This can be explained by the fact that 2-level fusion

needs longer operative time, more complex procedures, which may increase the possibility of iliac vein injury, iliac vein thrombosis, paralytic ileum, and pseudoarthrosis.

Our study had several limitations. First, although discography has the potential to assist in diagnosing the levels of disc degeneration, its reliance on the patient’s subjective pain response can be problematic where secondary gain may be an issue. Second, regardless of the details of how discography is performed, there are adverse effects caused by perforating the lumbar disc. Carragee et al<sup>32</sup> concluded that despite using modern discography techniques with small-gauge needles, there is still an increased risk of disc degeneration, disc herniation, changes in disc and endplate signal, and loss of disc height. Third, we only compared the ODI and VAS results and complication rate of different levels and did not examine the spinal fusion results. Finally, psychological and social factors such as spinal balance, habits, or confidence could contribute to compromising outcomes. Psychosocial factors are more important than biomechanical factors in determining the outcome, and the interactions between these determinants are more complicated than just “having problems.”

In conclusion, anterior instrumented fusion is a successful method of treating chronic DDLBP. The ODI and VAS results for monosegmental L4–L5, monosegmental L5–S1, and 2-segmental L4–L5/L5–S1 disc fusions have no difference. However, L4–L5 interbody fusion had better clinical results than 2-segmental L4–L5/L5–S1 disc fusion, and 2-segmental L4–L5/L5–S1 disc fusion had better clinical results than L5–S1 disc fusion. Two-segmental L4–L5/L5–S1 disc fusion also had a higher complication rate (27.3%). Therefore, care should be taken when 2-segmental L4–L5/L5–S1 disc fusion is performed. But there was no difference between the L4–L5 group (9.1%) and the L5–S1 group (12.5%). Additional long-term follow-up studies are needed to further justify the outcome.

## REFERENCES

- Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380:2163–2196.
- Kuslich SD, Ulstrom CL, Griffith SL, et al. The Bagby and Kuslich method of lumbar interbody fusion. *Spine*. 1998;23:1267–1279.
- Huang RC, Lim MR, Girardi FP, et al. The prevalence of contraindications to total disc replacement in a cohort of lumbar surgical patients. *Spine (Phila Pa 1976)*. 2004;29:2538–2541.
- Wong DA, Annesser B, Birney T, et al. Incidence of contraindications to total disc arthroplasty: a retrospective review of 100 consecutive fusion patients with a specific analysis of facet arthrosis. *Spine J*. 2007;7:5–11.
- Gornet MF1, Burkus JK, Dryer RF, et al. Five-year adjacent-level degenerative changes in patients with single-level disease treated using lumbar total disc replacement with ProDisc-L versus circumferential fusion. *J Neurosurg Spine*. 2012;17:504–511.
- Vamvanij V, Fredrickson BE, Thorpe JM, et al. Surgical treatment of internal disc disruption: an outcome study of four fusion techniques. *J Spinal Disord*. 1998;11:375–382.
- Goldner JL, Urbaniak JR, McCollum DE. Anterior disc excision and interbody spinal fusion for chronic low back pain. *Orthop Clin North Am*. 1971;2:2543–2568.
- Enker P, Steffee AD. Interbody fusion and instrumentation. *Clin Orthop*. 1994;300:90–101.

9. Pauza KJ, Howell S, Dreyfuss P, et al. A randomized, placebo-controlled trial of intradiscal electrothermal therapy for the treatment of discogenic low back pain. *Spine J*. 2004;4:27–35.
10. Shuff C, An HS. Artificial disc replacement: the new solution for discogenic low back pain? *Am J Orthop*. 2005;34:8–12.
11. Downie WW, Leatham PA, Rhind VW, et al. Studies with pain rating scales. *Ann Rheum Dis*. 1978;37:378–381.
12. Scott J, Huskisson EC. Vertical or horizontal visual analogue scales. *Ann Rheum Dis*. 1979;38:560.
13. McCormack HM, Horne DJL, Sheather S. Clinical applications of visual analogue scales: a critical review. *Psychol Med*. 1988;18:1007–1019.
14. Gaston-Johansson F. Measurement of pain: the psychometric properties of the Pain-O-Meter, a simple, inexpensive pain assessment tool that could change health care practices. *J Pain Symptom Manage*. 1996;12:172–181.
15. Fairbank JC, Couper J, Davies JB, et al. The Oswestry low back pain disability questionnaire. *Physiotherapy*. 1980;66:271–273.
16. Buenaventura RM, Shah RV, Patel V, et al. Systematic review of discography as a diagnostic test for spinal pain: an update. *Pain Physician*. 2007;10:147–164.
17. Carragee EJ, Lincoln T, Parmar VS, et al. A gold standard evaluation of the “discogenic pain” diagnosis as determined by provocative discography. *Spine*. 2006;31:2115–2123.
18. Waguespak A, Reynolds J, Schofferman J, Koestler M. Etiology of failed back surgery syndrome. Presented at the North American Spine Society, San Francisco, California, October 29–31, 1998.
19. Crock HV. Observations on the management of failed spinal operations. *J Bone Surg [Br]*. 1976;58:193–199.
20. Freemont AJ, Peacock TE, Goupille P, et al. Nerve ingrowth into diseased intervertebral discs in chronic low back pain. *Lancet*. 1997;350:178–181.
21. Saal JS, Franson RC, Dobrow R, et al. High levels of inflammatory phospho-lipase A2 activity in lumbar disc herniations. *Spine*. 1990;15:674.
22. Weatherley Cr, Prickett CF, O'Brien JP. Discogenic pain persisting despite solid posterior fusion. *J Bone Joint Surg [Br]*. 1986;68:142–143.
23. Ylinen P, Kinnunen J, Laasonen EM, et al. Lumbar spine interbody fusion with reinforced hydroxyapatite implants. *Arch Orthop Trauma Surg*. 1991;110:250–256.
24. Weinstein J, Claverie W, Gibson S. The pain of discography. *Spine*. 1988;13:1344–1348.
25. Stauffer R, Coventry M. Anterior interbody lumbar spine fusion. *J Bone Joint Surg [Am]*. 1972;54:756–763.
26. Wetzel FT, LaRocca H. The failed posterior lumbar interbody fusion. *Spine*. 1991;16:839–845.
27. Svante B, Tycho T, et al. Total disc replacement compared to lumbar fusion: a randomized controlled trial with 2-year follow-up. *Eur Spine J*. 2009;18:1512–1519.
28. Delamarter RB, Bae HW, Pradhan BB. Clinical results of ProDisc-II lumbar total disc replacement: report from the United States Clinical Trial. *Orthop Clin North Am*. 2005;36:301–313.
29. van Ooij A, Schurink GW, Oner FC, et al. Findings in 67 patients with recurrent or persistent symptoms after implantation of a disc prosthesis for low back pain. *Ned Tijdschr Geneesk*. 2007;151:1577–1584.
30. Siepe CJ, Mayer HM, Heinz-Leisenheimer M, et al. Total lumbar disc replacement: different results for different levels. *Spine (Phila Pa 1976)*. 2007;32:782–790.
31. Regan JJ. Clinical results of Charite? lumbar total disc replacement. *Orthop Clin North Am*. 2005;36:323–340.
32. Carragee EJ, Don AS, Hurwitz EL, et al. 2009 ISSLS Prize Winner: does discography cause accelerated progression of degeneration changes in the lumbar disc: a ten-year matched cohort study. *Spine (Phila Pa 1976)*. 2009;34:2338–2345.