Lateral Lumbar Interbody Fusion: Clinical and Radiographic Outcomes at 1 Year

A Preliminary Report

Amit K. Sharma, MD,* Christopher K. Kepler, MD,† Federico P. Girardi, MD,† Frank P. Cammisa, MD,‡ Russel C. Huang, MD,§ and Andrew A. Sama, MD†

**Study Design:** A retrospective review of patients’ radiographs and charts.

**Background:** The various methods of lumbar interbody fusion have been described in the literature. With the development of the lateral lumbar interbody fusion (LLIF) approach, a wider cage can be inserted in the intervertebral space without disrupting the anterior-posterior annulus or longitudinal ligament, with minimal danger to the retroperitoneal structures and the great vessels. There is a paucity of the literature on the radiographic and clinical outcome of this approach.

**Objective:** The purpose of this study is to assess the radiographic change in the coronal and sagittal plane alignment of the lumbar spine after the LLIF approach using XLIF cages (Nuvasive, Inc, San Diego, CA). Radiographic and clinical outcomes, and complications associated with the approach are also described.

**Methods:** A retrospective review of 43 consecutive patients’ preoperative, immediate postoperative, and 1-year follow-up radiographs was done. All patients had LLIF procedure performed for lumbar degenerative disc disease, spondylolisthesis, or de novo scoliosis. The radiographic measurements were taken to assess change in the sagittal and coronal plane alignment of the individual instrumented disc level, overall lumbar spine, and lumbar scoliotic curves. The radiographs were also analyzed for fusion at 1 year, end-plate fracture, and other complications. The patients’ hospital and clinic charts were reviewed to identify the complications and patient outcomes.

**Results:** There was a mean correction of 3.7 degrees (P ≤ 0.001) at each instrumented disc level in coronal plane in 87 instrumented levels. Similarly, there was a mean gain of 2.8 degrees (P ≤ 0.001) of lordosis at each level. In 25 patients with lumbar scoliosis (>10 degrees), mean scoliosis angle correction was 10.4 degrees (P = 0.001, 43%). There was no significant change in the overall coronal or sagittal plane alignment of the lumbar spine. The most common postoperative complication (25%) was anterior thigh pain, which was transitory in the majority of cases. End-plate breach was common at the instrumented disc levels; however, it was nonprogressive in most of the cases, and did not affect the fusion or alignment at the instrumented levels. The outcome scores were improved significantly at the final follow-up.

**Conclusion:** The LLIF approach is effective in correcting the coronal plane deformity and in gaining lordosis at individual instrumented levels. They parallelize adjacent end plates to correct the lumbar scoliotic curves. The complications are mostly approach-related and transitory. A larger cohort with long-term follow-up is required to establish the advantages and shortcomings of the procedure.

**Key Words:** lateral lumbar interbody fusion, degenerative, cage

(J Spinal Disord Tech 2011;24:242–250)

Sagittal and coronal plane malalignment is common in the aging lumbar spine secondary to continued degeneration with asymmetric collapse of the intervertebral disc spaces.1–5 This leads to poor body posture, back pain, and neurologic deterioration owing to decreased foraminal height with nerve root compression on the concave side and nerve stretch on the convex side of the deformity.1,2,6 An improvement in the function and validated outcome measures has been reported after the correction of the coronal plane deformity and restoration of lumbar lordosis in the degenerative spine.7–10

Various techniques have been reported in the literature for the correction of degenerative lumbar deformity with instrumentation and fusion using pedicle screw systems and/or various types of interbody cages. Traditionally, the cages were placed from either the posterior approach as in the posterior lumbar interbody fusion (PLIF) and trans-foraminal lumbar interbody fusion (TLIF), or through an anterior approach in the anterior lumbar interbody fusion (ALIF), using autograft bone, allograft bone, metal cages, or poly-ether-ether-ketone (PEEK) cages.7,11–13 Recently, there has been increasing interest in minimally invasive interbody fusion techniques using interbody fusion cages inserted through...
a lateral lumbar interbody fusion (LLIF) approach.\textsuperscript{14,15} One advantage of this procedure is direct access of the disc space through the psoas muscle, reducing the danger of injury to the retroperitoneal structures, great vessels, or the sympathetic plexus.\textsuperscript{14}

The literature is sparse on the use of the LLIF approach for lumbar degenerative disorders.\textsuperscript{6,14} We present our initial experience with LLIF using the PEEK XLIF cages, and report on preoperative and postoperative lumbar spine alignment in the sagittal and coronal planes and perioperative complications associated with this procedure and patient outcome at 1 year.

**MATERIALS AND METHODS**

Forty-three patients underwent the LLIF procedure using XLIF PEEK cages and had a minimum of 1 year of radiographic and clinical follow-up (Table 1). All patients had symptomatic degenerative lumbar spondylosis with or without listhesis or de novo scoliosis associated with back pain. The patients with preexisting posterior instrumentation/fusion at the operative level, those with predominant leg pain, and patients who had had associated posterior decompression performed were excluded from the study. The patients were treated with activity modification, physical therapy, chiropractic manipulations, pain medications, and/or steroid injections before operative management.\textsuperscript{2,4–6,16} The radiographs, magnetic resonance imaging (MRI), and computed tomography (CT) scan with or without myelography were used to assess the spine preoperatively.

A total of 87 disc levels underwent LLIF in 43 patients (Figs. 1–5): 20 one-level procedures, 6 two-level procedures, 13 three-level procedures, and 4 four-level

**TABLE 1. Patients’ Characteristics**

| Characteristic                        | Value                      |
|---------------------------------------|----------------------------|
| Age (y)                               | 63.9 ± 10.2 (40–82)        |
| Sex                                   | 16 men, 27 women           |
| BMI (kg/meter\(^2\))                 | 26.0 (18.1–39.9)           |
| Surgery duration (h)                  | 3.1 (1.5–5.0)              |
| Estimated blood loss (cc, for anterior part of the surgery only) | 200 (50–350) |
| Hospital stay (d)                     | Stand alone-3.4 (3–5)       |
|                                      | With posterior instrumentation- 8.2 (3–28) |
|                                      | Degenerative scoliosis-25   |
|                                      | Degenerative spondylolisthesis-7 |
|                                      | Degenerative disc disease ± stenosis-11 |
|                                      | Stand alone anterior cages-16 (10) |
|                                      | With lateral plate and unilateral screw fixation-9 (9) |
|                                      | With pedicle screw fixation-62 (24) |

BMI indicates body mass index.

![Figure 1](https://example.com/f1.png)

**FIGURE 1.** A single-level lateral lumbar interbody fusion with pedicle screw fixation.
procedures. Nine L1-2 (10%), 27 L2-3 (31%), 26 L3-4 (30%), and 25 L4-5 (29%) discs levels were instrumented. Ten patients had stand-alone anterior fusion without posterior instrumentation at 16 disc levels (18%). Another 33 patients underwent LLIF followed by posterior instrumentation, either under the same anesthesia or staged at an interval of 4 to 7 days (in 4 patients at 11 disc levels).

In all the cases, instrumented lumbar disc levels were fused using 10-degree lordotic XLIF cages. Side-to-side cage size was decided by the width of the end plates at that level based on intraoperative fluoroscopic guidance. The maximum distraction achieved during discectomy using the trial inserts provided guidance as to the height of the cage. Bone morphogenetic protein or bone graft (demineralized bone matrix, autograft, allograft, bone marrow aspirate) was used to fill the cage to enhance fusion, depending on the surgeon’s preference. In cases in which the fusion extended to the sacrum, the L5-S1 level was addressed by either an ALIF or PLIF procedure with posterior instrumentation as the position of the iliac crests and neurovascular structures prevents access to the L5-S1 disc through the LLIF approach.6,14

FIGURE 2. A, Preoperative and (B) postoperative radiographs of the lateral lumbar interbody fusion for adjacent level degeneration.
The technique for XLIF instrumentation has been described earlier in detail. In this study, the spine was approached from the concavity of the scoliotic curve with the intention to approach several levels through a single skin incision placed at the center of the rotation of the scoliotic curve. In cases without significant coronal plane deformity, a left-sided approach was preferred because of the relatively anterior position of retroperitoneal vasculature on the left side. The angle of the L4-5 disc in relation to the height of the iliac crest was another major determinant in deciding the side of the approach as the iliac crest can block access to a caudally angled L4-5 disc. A minimally invasive technique with tubular expandable retractors or a standard retroperitoneal approach was used depending upon the number of the levels to be fused and the surgeon’s preference; however, a separate posterior incision was not used to identify the approach to the psoas muscle as originally described. In all cases, electromyography probes (NeuroVision monitor, Nuvasive, Inc., San Diego, CA) were used to avoid injury to the lumbar plexus at the time of dissection through the psoas muscle.

Preoperative, immediate postoperative, and 1-year follow-up radiographs were reviewed. In patients with staged anterior and posterior procedures, standing radiographs were taken before posterior instrumentation. Radiographic parameters measured by 2 independent observers from standing radiographs were lumbar lordosis (L1 superior end plate to S1 superior end plate), coronal plane alignment between superior end plates of L1 and S1, and sagittal and coronal plane alignment at all individually instrumented levels by measuring the adjacent end plates. In patients with lumbar scoliosis (Cobb angle >10 degrees), the measurements were taken to assess the maximum curve magnitude both preoperatively.
and postoperatively. End-plate fractures, cage malpositioning, and achievement of fusion were also recorded. The assessment of fusion was based on the presence of a bridging bone across the disc space and lack of instability in the flexion-extension radiographs, and the absence of pedicle screw loosening.\textsuperscript{11,19} A thin-slice CT scan was obtained when radiographs were nondiagnostic or nonunion was suspected clinically. A review of the patients’ charts was done to identify the complications in the perioperative period. The patients’ outcome scores were collected preoperatively and at 6 weeks, 3 months, 6 months, and at 1 year.

End-plate fractures after XLIF cage insertion were identified on the lateral radiographs of the spine. Different grades were assigned according to the classification system shown in Figure 6: grade 0 represents a normal end plate without fracture, grade I represents a breach of the end plate at one side (anterior or posterior)
of the cage, grade II represents a fracture of the end plate at both the anterior and posterior sides of the cage, whereas grade III signifies an end-plate fracture with cage subsidence of more than one-third of the cage height into the vertebral body.

All the measurements were collected in an Excel spreadsheet (Microsoft, Inc., Richmond, VA). Means and standard deviations were obtained for different variables. Preoperative and postoperative measurements and values between the different subgroups were compared using the Student t test with statistical significance set at a P value of <0.05.

RESULTS

In coronal plane, there was a mean 3.7 degrees of correction in the scoliotic angle of the adjacent end plates at individual instrumented levels (Table 2). Similarly, there was a mean gain of 2.8 degrees of lordosis at each instrumented level at 1 year. In 25 patients with lumbar scoliosis (scoliotic curve more than 10 degrees), mean correction in the maximal Cobb angle was 10.4 degrees (43%). There was no statistically significant difference between the preoperative and postoperative L1-S1 alignment in either the coronal or sagittal plane. Intraclass correlation (ICC) was calculated to measure interobserver and intraobserver reliability for angular measurements and displayed values of 0.90 and 0.94, respectively, indicative of high reliability.

Complications after the LLIF approach and instrumentation are given in Table 3. The most common postoperative complication of the procedure was anterior thigh pain and weakness of the hip flexors. Of the 17 patients who had neurologic complications, 7 were 1-level, 4 were –two-levels, 4 were 3-level, and 2 –were 4-level fusion. One patient had thigh numbness contralateral to the side of the approach. There was one case of retroperitoneal bleeding not recognized at the time of the initial surgery presented with abdominal pain while still in the hospital and underwent embolization of the corresponding segmental vessel.

End-plate breach was common (Figs. 6, 7). There was no significant change in the sagittal or coronal correction at the individual instrumented levels in cases with the progression of the end-plate fracture. Of the end-plate breach that progressed at the final follow-up (n = 11), only 2 levels were stand-alone cage instrumentation. There was 1 case of anterior cage malpositioning with the cage being partially anterior to the anterior vertebral margin noted in the immediate postoperative radiographs. Nonunion at the L4-5 level was found in 1 patient who also had posterior instrumentation at 1 year. This patient was treated by revising the XLIF cage. Another patient with four levels (L1-5) of stand-alone fusion had nonunion at all 4 levels with the loss of scoliotic curve correction. This patient was being treated conservatively with a brace till the last follow-up. There were 2 cases of atraumatic vertebral body fracture presented at 6 weeks postoperatively, which were treated conservatively in 1 case and with kyphoplasty in the other. Both patients had fusion at 1-year follow-up.

| Table 2. Angular Change at Individual Instrumented Level, Scoliotic Curve, and Overall Lumbar Spine After Fusion Using LTIF Approach* |
|---------------------------------------------------------------|
| **Preop** | **Immediate Postop** | **1-Year Follow-up** |
|---------------------------------------------------------------|
| Individual disc level (coronal plane) | 5.2 ± 4.7 (0–18.8) | 1.3 ± 2.5 (–6–11) | 1.5 ± 2.8 (–8–10) |
| | | P ≤ 0.001 | P ≤ 0.001 |
| Individual disc level (sagittal plane) | 5.4 ± 5.3 (–5–24) | 8.5 ± 4.5 (–5–18) | 8.2 ± 4.9 (0–20.4) |
| | | P ≤ 0.001 | P ≤ 0.001 |
| Scoliotic curve (n = 25) | 24 ± 14.4 (10.6–72) | 12.2 ± 11.6 (–3–55) | 13.6 ± 15.6 (–17–57) |
| | | P = 0.001 | P = 0.001 |
| L1-S1 (coronal plane) | 10.0 ± 9.3 (0–40.5) | 6.7 ± 6.7 (–1.8–26.0) | 6.8 ± 8.2 (–6.1–34.3) |
| | | P = 0.06 | P = 0.11 |
| L1-S1 (sagittal plane) | 47.8 ± 15.1 (15.2–79.3) | 48.3 ± 12.0 (17.7–76.7) | 49.3 ± 12.5 (16.9–70.4) |
| | | P = 0.86 | P = 0.63 |

*All the values are in degrees ± standard deviation (range).
The patients had significant improvement in their outcome scores at 1 year other than the short-form-12 mental component score (SF-12 MCS) (Table 4).

**DISCUSSION**

Anterior lumbar fusion has a superior biological environment in comparison with the posterior lumbar fusion because of the large surface area available between vertebral bodies. Better structural support is provided with interbody cages in comparison with the posterolateral spine fusion, a characteristic especially important in elderly patients with osteoporotic bones.7,12,20,21 The LLIF approach, which allows interbody fusion with less risk to the peritoneal contents and retroperitoneal vascular structures, is a relatively new technique first described by Bergey et al.15 Ozgur et al14 first described the use of the XLIF cage using this approach for lumbar interbody fusion. The literature is sparse on the clinical and radiographic outcomes of the LLIF approach.

There are several advantages of the LLIF approach using wide interbody cages. The subsidence of the cage is

![FIGURE 7. A, Lateral lumbar radiograph showing grade I (L4-5) and grade III (L3-4) end-plate fracture. B, Sagittal midline computed tomography cut showing a grade II end-plate fracture.](image-url)
common with the posterior lumbar fusion techniques (PLIF and TLIF).\textsuperscript{7,19} ALIF cages, although large, rest on the weaker central region of the end plate without the benefit of support from the stronger apophyseal ring, which may lead to subsidence.\textsuperscript{11,21} The surface area of the PLIF and TLIF cages is much smaller and so is the amount of the bone graft that can be placed in these cages. With the LLIF approach, however, relatively wider cages can be used, which rest on a strong peripheral cortical bone on either side minimizing the risk of cage subsidence. Another advantage of the LLIF cages is the inherent stability lent by the native anatomic structures that are preserved with this technique. A breach of both the annulus and a longitudinal ligament occurs in the ALIF, PLIF, and TLIF approaches. As access to only the middle third of the disc is required for cage insertion, and the anterior longitudinal ligament (ALL) and posterior longitudinal ligament (PLL) are not disrupted in LLIF approaches, there is increased inherent stability in the construct. An XLIF cage was used as a stand-alone device in 10 patients without loss of correction at 1-year follow-up in our series. In addition, either a side plate placed through the same minimally invasive lateral approach or pedicle screws can be used for added stabilization.

A direct lateral retroperitoneal approach avoids exposure of the abdominal viscera, large vessels, and sympathetic nerves. The potential for injury to these structures is one of the major disadvantages with the traditional anterior approaches.\textsuperscript{7,11} With the PLIF and TLIF fusion cages, injury to nerves, dural tear, and perineural fibrosis are potential complications.\textsuperscript{11,22} In revision procedures, it is very difficult to dissect through the scar tissue, which is adherent to the dura and the nervous structures, to reach the interbody space through a posterior approach. The risk of damage to these structures may be minimized by the LLIF approach.

The restoration of lumbar lordosis and correction of lumbar coronal plane deformity is associated with improved functional and subjective outcomes in adults with degenerative lumbar spondylosis.\textsuperscript{7,8} Average curve correction in our series was 43\% of maximal Cobb angle for patients with >10 degrees of lumbar scoliosis with the maintenance of the correction at 1 year. This was similar to the correction obtained in other series of patients treated for degenerative scoliosis.\textsuperscript{9,10} Anand et al\textsuperscript{6} reported their experience with minimally invasive technique for correction of degenerative lumbar scoliosis using XLIF/DLIF (Direct Lateral Interbody Fusion, Medtronic Sofamor Danek, Memphis TN) cages with Axia-LIF (Axial Lumbar Interbody Fusion, Transl, Wilmington NC) interbody fusion used for L5-S1 level. Mean Cobb angle correction in their series was from 18.9 degrees preoperatively to 6.2 degrees after surgery with improvement in the visual analog scale (VAS) for the back pain in the immediate post-op period.

There are several limitations of the LLIF approach.\textsuperscript{14,18} Access to the L4-5 disc level can be obstructed by a high iliac crest or aberrant lumbar plexus anatomy. Similarly, access to the L1-2 level can sometimes be hindered by lower ribs. Trauma to the lumbar plexus is a potentially disastrous complication that can occur if adequate caution is not exercised while dissecting through the psoas muscle. However, the NeuroVision monitors are designed to detect the lumbar plexus at a safe distance before significant retraction. Postoperative anterior thigh pain is common, though transitory.\textsuperscript{14,15,18} The progressive ventral migration of the lumbar plexus with distal lumbar levels has been reported that puts lower lumbar nerve roots at increased risk of trauma during the surgery.\textsuperscript{23} The incidence of transient thigh pain (25\%) and quadriceps weakness (9\%) in our series was similar to the reported incidence in the literature.\textsuperscript{6,15} These symptoms were likely related to the psoas muscle trauma inherent in this approach. There was no associated sensory change. Complete recovery of the symptoms is usual within 6 weeks.

One of the major limitations of this study was the small number of patients in each subgroup. A valid comparison could not be made between the stand-alone anterior and anterior-posterior cases. The number of the patients in each subgroup was limited when they were classified by the number of the levels fused by the LLIF approach. Hence a valid comparison could not be made whether multilevel fusion using XLIF cages was affecting lumbar lordosis more significantly than in patients with 1 or 2-level fusion. A minimum of 30\% improvement in the outcome scores is required to be clinically significant,\textsuperscript{24} which was noted for VAS and ODI.

We found that the LLIF approach with wide cages was effective in correcting coronal plane deformity; however, lumbar lordosis was not much affected. One reason for this might be the variable anteroposterior positioning of the cage in the fish-mouthed disc space. An anteriorly placed cage will provide more lordosis at the instrumented level, whereas a cage placed in the middle third might be totally accommodated between the biconcave end plates and may not provide any sagittal plane correction. In our series, many patients had only 1 or 2-level fusion carried out, and the correction achieved at these levels may not get reflected in the overall lumbar lordosis with adjacent mobile segments.

In conclusion, LLIF is an effective approach in our initial experience of the lumbar interbody fusion with acceptable outcome at the short-term follow-up. Majority of the complications were transitory in nature and some of them might reflect the learning curve associated with this new technique. Further studies with larger numbers of patients and long-term follow-up are required to

| TABLE 4. Outcome Score at 1 Year |
|----------------------------------|
|                                | Preoperative | At 1 Year | P     |
| Visual analog Score (Low back pain) | 8.2          | 4.6       | 0.001 |
| Oswestry Disability Index (ODI)    | 42.6         | 31.5      | <0.001 |
| SF-12 (physical component score)  | 26.9         | 35.3      | <0.001 |
| SF-12 (mental component score)    | 41.7         | 45.3      | 0.33  |

SF-12 indicates short form 12.
establish the true benefits and shortcomings of the LLIF approach.

ACKNOWLEDGMENT

The authors thank Mr Brett DeMars, MLIS, Sr Library Assistant, UMMC Medical Library, 2450 Riverside Ave, Minneapolis MN 55454 for his help in the preparation of the manuscript.

REFERENCES

1. Ploumis A, Transfeldt EE, Denis F. Degenerative lumbar scoliosis associated with spinal stenosis. Spine J. 2007;7:428–436.
2. Aebi M. The adult scoliosis. Eur Spine J. 2005;14:925–948.
3. Berven SH, Deviren V, Mitchell B, et al. Operative management of degenerative scoliosis: an evidence-based approach to surgical strategies based on clinical and radiographic outcomes. Neurosurg Clin N Am. 2007;18:261–272.
4. Oskouian RJ Jr, Shaffrey CI. Degenerative lumbar scoliosis. Neurosurg Clin N Am. 2006;17:299–315.
5. Daffner SD, Vaccaro AR. Adult degenerative lumbar scoliosis. Am J Orthop. 2003;32:77–82.
6. Anand N, Baron EM, Thaiyathanan G, et al. Minimally invasive multilevel percutaneous correction and fusion for adult lumbar degenerative scoliosis: a technique and feasibility study. J Spinal Disord Tech. 2008;21:459–467.
7. Hsieh PC, Koski TR, O’Shaughnessy BA, et al. Anterior lumbar interbody fusion in comparison with transforaminal lumbar interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance. J Neurosurg Spine. 2007;7:379–386.
8. Ploumis A, Liu H, Mehbod AA, et al. A correlation of radiographic and functional measurements in adult degenerative scoliosis. Spine (Phila, Pa 1976). 2009;34:1581–1584.
9. Wu CH, Wong CB, Chen LH, et al. Instrumented posterior lumbar interbody fusion for patients with degenerative lumbar scoliosis. J Spinal Disord Tech. 2008;21:310–315.
10. Paterdi DB, Kebaish KM, Cascio BM, et al. Posterior only versus combined anterior and posterior approaches to lumbar scoliosis in adults: a radiographic analysis. Spine (Phila Pa 1976). 2007;32:1551–1554.
11. Blumenthal SL, Ohnmeiss DD. Intervertebral cages for degenerative spinal diseases. Spine J. 2003;3:301–309.
12. Janssen ME, Lam C, Beckham R. Outcomes of allogenic cages in anterior and posterior lumbar interbody fusion. Eur Spine J. 2001;10(2 suppl):S158–S168.
13. Groth AT, Kuklo TR, Kleme WR, et al. Comparison of sagittal contour and posterior disc height following interbody fusion: threaded cylindrical cages versus structural allograft versus vertical cages. J Spinal Disord Tech. 2005;18:332–336.
14. Ozgur BM, Aryan HE, Pimenta L, et al. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. Spine J. 2006;6:435–443.
15. Bergey DL, Villavicencio AT, Goldstein T, et al. Endoscopic lateral transpsoas approach to the lumbar spine. Spine (Phila Pa 1976). 2004;29:1681–1688.
16. Tribus CB. Degenerative lumbar scoliosis: evaluation and management. J Am Acad Orthop Surg. 2003;11:174–183.
17. Eck JC, Hodges S, Humphreys SC. Minimally invasive lumbar spinal fusion. J Am Acad Orthop Surg. 2007;15:321–329.
18. Shen FH, Samartzis D, Khanna AJ, et al. Minimally invasive techniques for lumbar interbody fusions. Orthop Clin North Am. 2007;38:373–386.
19. Schiffman M, Brau SA, Henderson R, et al. Bilateral implantation of low-profile interbody fusion cages: subsidence, lordosis, and fusion analysis. Spine J. 2003;3:377–387.
20. Gödde S, Fritsch E, Dienst M, et al. Influence of cage geometry on sagittal alignment in instrumented posterior lumbar interbody fusion. Spine (Phila Pa 1976). 2003;28:1693–1699.
21. Hart RA, Prendergast MA. Spine surgery for lumbar degenerative disease in elderly and osteoporotic patients. Instr Course Lect. 2007;56:257–272.
22. DiPaola CP, Molinari RW. Posterior lumbar interbody fusion. J Am Acad Orthop Surg. 2008;16:130–139.
23. Benglis DM, Vanni S, Levi AD. An anatomical study of the lumbosacral plexus as related to the minimally invasive transpsoas approach to the lumbar spine. J Neurosurg Spine. 2009;10:139–144.
24. Ostelo RW, Deyo RA, Straford P, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine (Phila Pa 1976). 2008;33:90–94.