Decompression Surgery For Lumbar Spondylolysis Without Fusion: A Review Article

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Citation

Abstract
The various techniques reported in the literature for surgical treatment of lumbar spondylolysis can be grouped into three categories: direct repair of the lysis, lumbar inter-segmental fusion, and decompression. Direct repair of spondylolysis has been widely used to treat young patients in whom severe disc degeneration and instability are not apparently combined. When severe disc degeneration causing low back pain and/or instability is observed, lumbar intersegmental fusion has been performed. Gill et al. (1955) were the first to describe non-fusion decompression surgery in patients with radiculopathy due to lumbar spondylolysis. The short-term clinical results were reported to be good. However, some authors have reported that Gill's laminectomy results in further postoperative vertebral slippage. Biomechanically, finite element analysis revealed that disc stress increased 2-fold after Gill's laminectomy. This increased disc stress after surgery may facilitate disc degeneration, which may lead to slippage. Recently, we developed a procedure for minimally invasive decompression of the nerve root affected by lumbar spondylolysis that is carried out using a spinal endoscope. Finite element analysis showed that endoscopic decompression did not change the lumbar kinematics in terms of disc stresses after surgery.

CONVENTIONAL DECOMPRESSION SURGERY (GILL’S LAMINECTOMY)

CLINICAL STUDIES
Lumbar spondylolysis is considered to be a stress fracture of the pars interarticularis, which occurs in approximately 6% of the entire population. This disorder is usually clinically benign; however, in certain patients, surgical treatment is required to lessen the symptoms. Lumbar spondylolysis comprises two pathological entities, inducing symptoms such as low-back pain and leg pain: 1) pseudoarthrosis of a fractured pars defect produces radiculopathy by compressing the nerve root; and 2) discogenic problems causing instability and low-back pain. The surgical strategy should be tailored to these pathological entities. To treat radiculopathy, decompression of the nerve root is required, whereas spinal fusion is necessary to treat discogenic pain and spinal instability. When these entities present simultaneously, both decompression and fusion are needed. Based on this concept, decompression surgery has been conducted to treat the nerve root impingement due to the lumbar spondylolysis.

Gill et al. first described decompression surgery without fusion in 1955. Their decompression procedure included excision of the loose lamina, removal of fibro-cartilaginous masses at the pars defects, removal of adhesions of the dura and ligamentum flavum, and careful dissection of the nerve root to be freed through the intervertebral foramen. Also, they recommended the partial removal of the pedicle if necessary. In 1984, Gill reported a follow up of clinical results (average, 71 months) of Gill's laminectomy without spinal fusion. In more than 80% of the patients, results were satisfactory. Amuso et al. performed Gill's laminectomy in 33 adult patients, and reported their clinical outcome at an average follow up of 7 years in 1970. They concluded that decompression alone was beneficial in adults with pain due to nerve root compression, as simplicity of performance with decreased morbidity yielded satisfactory results, and as such should be considered an option for the surgical treatment of lumbar spondylolysis/spondylolisthesis.

Osterman et al. reported long-term follow-up data (ranging between 5 and 20 years; mean 12 years) obtained in 75 patients in whom Gill's operation was performed. The primary clinical results evaluated 1 year after the surgery indicated that in 83% of the patients these were satisfactory; however, the late results at an average of 12 years indicated that 75% of them had satisfactory results. They also reviewed them radiologically. In 27% of the patients, further progression of the spondylolisthesis was observed, usually in
connection with disc degeneration. However, they showed this progression did not affect the clinical results of treatment. Davis and Bailey (3) reviewed data at an average of 77 months in 39 patients who underwent the Gill's laminectomy. They obtained clinical and radiological results similar to those obtained by Osterman et al. (14). Thus, they stated that the surgical decompression alone could be indicated for patients with nerve root symptoms aged over 40.

BIOMECHANICAL ANALYSIS

The biomechanical behavior of spines can be studied by Quantification of three-dimensional load-displacement behavior using fresh cadaveric spines (10, 12, 13, 15), and/or Finite element (FE) analyses (8, 9, 11, 12, 19, 20, 21, 23, 24, 25, 26).

To understand the biomechanical effects of decompression surgery, we used FE analysis. Figure 1 shows a 3-D lumbar FE intact lumbar spine model. The stress concentrations within the spine structures can be calculated using this model. Numerous clinical and biomechanical issues in a variety of spinal disorders have been investigated using this technique.

Figure 1
Figure 1: A 3D finite element (FE) intact model of THE L3-L5 segment.

FINITE ELEMENT MODEL OF GILL’S LAMINECTOMY

The intact FE lumbar model (L3 to L5 segments) was modified to simulate bilateral spondylolysis at L4. Cracks of 1.0 mm were created at both pars interarticularis to simulate bilateral spondylolysis, Figure 2-a. Figure 2-b depicts the FE model of Gill's procedure. The loose lamina of L4 was removed. Simultaneously all surrounding ligaments such as the flavum, interspinous and supraspinous were also removed.

Figure 2
Figure 2: FE models of L4 spondylolysis and Gill's laminectomy.

**ANALYSIS**

Von Mises stress distribution in various structures around the L4/5 disc and changes in the intradiscal pressure (IDP) were analyzed in flexion, extension, lateral bending and axial rotation in response to 400 N of axial compression and 10.6 Nm moment. The IDP and stresses were compared between the models simulating spondylolysis and Gill's laminectomy (21).

**STRESS DISTRIBUTION**

The stresses at the various regions around the L4/5 disc were calculated; i.e. anterior L4 endplate, posterior L4 endplate, anterior annulus fibrosus, nucleus pulposus, posterior annulus fibrosus, anterior L5 endplate and posterior L5 endplate. At all evaluated areas, the Von Mises stresses in the Gill's model were higher than in the spondylolysis model (pre-operation condition) during flexion motion. Figure 3 depicts the stress distribution of the nucleus pulposus and annulus fibrosus at L4/5. The highest stress value at the annulus fibrosus for each model was 0.65 and 1.25 MPa, for spondylolysis (Fig. 3-a) and Gill's laminectomy model (Fig. 3-b), respectively. The highest stress value at the nucleus pulposus for each model was 0.09 and 0.16, accordingly. The stresses at adjoining endplates showed about 2-fold increases in Gill's procedure compared to the spondylolysis models. In the other motions, i.e. extension, lateral bending, or axial rotation, the results were similar among the models.
Figure 3
Figure 3: Stress distribution of the nucleus pulposus and annulus fibrosus at L4/5 of spondylolysis and Gill's laminectomy models. The highest stress value at the annulus fibrosus for each model was 0.65 and 1.25 MPa, for spondylolysis and Gill's laminectomy model, respectively. The highest stress value at the nucleus pulposus for each model was 0.09 and 0.16, accordingly.

The analyses revealed approximately a 2-fold increase in the stresses at the anterior spinal column such as endplates of L4 and L5, the annulus fibrosus, and intradiscal pressure across L4/5 during the flexion motion after Gill's laminectomy. This 2-fold increase may contribute to disc degeneration, causing forward slippage over time following surgery using Gill's procedure (21).

MINIMALLY INVASIVE ENDOSCOPIC DECOMPRESSION CLINICAL STUDIES
The surgical indication of the endoscopic decompression was decided based on the clinical indication of Gill's laminectomy. Osterman et al. (14) concluded that the main indication for surgical decompression was painful spondylolisthesis with nerve root–related symptoms in patients older than 40 years of age. Furthermore, the authors emphasized that the operation was basically contraindicated in adolescents. Davis and Bailey (3) stated that spinal fusion was needed in pediatric patients to prevent likely vertebral slippage after decompression surgery. Thus, the surgery-related indications for our endoscopic technique were: 1) radiculopathy without low-back pain; 2) absence of spinal instability on dynamic radiographs; and 3) age older than 40 years.

This technique (26) is an application of the MED (microendoscopic discectomy) method established by Foley and Smith (4). Figures 4 and 5 provide detailed schemas of this procedure. A longitudinal skin incision of 16 mm in length was made 1 cm lateral to the affected side from the midline, after the spondylolytic level was confirmed with an image intensifier. A guide pin was then placed onto the caudal edge of the cranial adjacent lamina of the spondylotic level. A tubular retractor was placed to ensure preservation of the surgical space. Endoscopically, laminotomy and removal of the ligamentum flavum were conducted. The affected nerve root was identified after this step (Fig. 4). Usually, the nerve root is compressed by the proximal stump at the ragged edge of the spondylotic lesion, and by the fibrocartilaginous mass. Thus, to decompress the affected nerve root, these masses are removed (Fig. 5). In most cases, the osseous ragged edge of spondylolysis was seen to compress tightly the nerve root and it was very difficult to remove this bony spur using a rongeur alone. Usually, the osseous edge was thinned using a high-speed drill or a specially made chisel first so that the edge could be safely removed endoscopically. The osseous mass was then safely and completely removed using a Kerrison rongeur or a curved curette.

Figure 4
Figure 4: Surgical procedure of endoscopic decompression (Step 1)
Eleven patients who fulfilled these criteria underwent endoscopic decompressive surgery between January 2001 and July 2003. Their mean age was 61.7 years (range: 42–70 years). Ten patients had bilateral pars defects at L5. No slippage was present in six patients; whereas Meyerding Grade I slippage was demonstrated in four. In the remaining patient we observed a two-level bilateral pars defects at L4 and L5 but no subluxation. No patient suffered low-back pain, but leg pain was present.

In all patients a radiculogram of the affected nerve root was conducted before surgery to confirm the impingement of the nerve root by the osseous ragged edge. The proximal stump of the osseous ragged edge of the spondylolytic lesion, which compressed the nerve root, was evaluated by CT scan before surgery. Postoperatively, the laminotomy area was assessed using plain anteroposterior radiographs, and resection was confirmed on CT scans. At the final follow-up examination, criteria established originally by Gill were used to evaluate clinical outcome.

Decompression surgery was successfully performed endoscopically for 14 pars defects in 11 patients. Two patients had bilateral decompression at the same level, and one patient underwent two levels decompression at the same side. For the remaining 8 patients, single side decompression, inducing leg symptoms, was conducted. We were never required to convert the endoscopic procedure to a conventional open procedure. No complication, such as dural laceration or postsurgical epidural hematoma, was observed intra- or postoperatively. Operative time ranged from 1.5 to 4 hours, and the mean time per level was 2.3 hours. For getting used to the technique of endoscopic decompression requires, the certain learning curve could exist. At the initial several cases, longer operation time should be required. However, after certain cases, the time required could be shortened. Leg pain disappeared or decreased in all patients, and they returned to their daily activities within 3 weeks. The follow-up period ranged from 3 to 30 months (mean 10.8 months). Based on Gill’s criteria, excellent, good and fair clinical outcomes were demonstrated respectively in four, six, and one patients at the final follow-up examination. None of the patients showed a poor outcome. Radiologically, there was no further slippage, indicated as % of slippage after the surgery. The follow-up period was not long enough to conclude the significant outcome; thus, the long-term follow-up study is warranted.

Figure 6 shows plain radiographs and CT scans from a 60-year-old male patient pre- and post-operatively. The laminotomized area was observed on the plain radiograph, and on CT scan, the ragged edge was removed after surgery. Figure 7 shows pre- and post-operative CT scans from a 70-year-old man. The proximal stump of the osseous ragged edge of the spondylolytic lesion observed on the left side was removed after surgery.
Figure 7
Figure 7: CT scans before and after endoscopic surgery in a 70-year-old man with L5 spondylolysis.

BIOMECHANICAL STUDIES
FINITE ELEMENT MODEL
For the biomechanical analysis of the endoscopic surgery, the L4 spondylolysis FE model (Fig. 8-a) was also modified. Figure 8-b demonstrates the finite element model simulating our endoscopic decompression procedure on the left side. According to the procedure, the surgical method involves fenestration at the left L3/4 level: i.e. L3 and L4 laminotomy, partial medial facetectomy at L3/4, and curettage of the pars defect (21).

Figure 8
Figure 8: FE models of L4 spondylolysis and endoscopic decompression.

ANALYSIS
Von Mises stress distribution in various structures around the L4/5 disc and changes in the intradiscal pressure (IDP) were analyzed in flexion, extension, lateral bending and axial rotation in response to 400 N of axial compression and 10.6 Nm moment. The IDP and stresses were compared between the models simulating spondylolysis and two surgical procedures.

STRESS DISTRIBUTION
The stresses at the various regions around the L4/5 disc were calculated; i.e. anterior L4 endplate, posterior L4 endplate, anterior annulus fibrosus, nucleus pulposus, posterior annulus fibrosus, anterior L5 endplate and posterior L5 endplate. At all evaluated areas, the Von Mises stresses in the spondylolysis and endoscopic model were similar. Figure 9 depicts the stress distribution of the nucleus pulposus and annulus fibrosus at L4/5. The highest stress value for each model was 0.65 for both the spondylolysis and endoscopic decompression models. The endoscopic procedure did not lead to any increase in stresses in various spinal elements nor in intradiscal pressure. During the endoscopic surgery, supra- and inter-spinous ligaments are kept intact. Besides, this procedure can be done with minimally invasiveness to the paravertebral muscles. Thus, endoscopic decompression of spondylolysis is a minimally invasive method to relieve radicular pain without further destabilizing the spine (21). As described in the article (21), the limitation of this FEM study was the lumbar level, where the spondylolysis was simulated. The spondylolysis was simulated at L4 in the model; however, over 80% of the lysis occurs at L5.
Figure 9

Figure 9: Stress distribution of the nucleus pulposus and annulus fibrosus at L4/5 of spondylolysis and endoscopic decompression models.

CONCLUSION

We described two kinds of decompression surgeries for lumbar spondylolysis. Unlike the traditional Gill’s laminectomy, endoscopic decompression does not alter the lumbar kinematics after surgery. Minimally invasive endoscopic decompression surgery without fusion is a recommendable alternative for the surgical treatment of lumbar spondylolysis.

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