Eklem Hastalıkları ve Cerrahisi
Joint Diseases and Related Surgery

Original Article / *Çalışma - Araştırma*

Joint Dis Rel Surg
2005;16(2):111-117

A comparison between interspinous ligamentoplasty, posterior interbody fusion, and posterolateral fusion in the treatment of grade I degenerative lumbar spondylolisthesis

Derece I dejeneratif lomber spondilolistesis tedavisinde interspinöz ligamentoplasti, posterior interbody füzyon ve posterolateral füzyonun karşılaştırılması

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Objectives: Interspinous ligamentoplasty (ILP) is a relatively new procedure designed to stabilize mild degenerative lumbar instability. We compared surgical outcomes of ILP, posterior lumbar interbody fusion (PLIF), and posterolateral fusion (PLF) and evaluated radiographic factors affecting the success of ILP.

Patients and methods: We retrospectively reviewed the clinical data of 103 patients who underwent decompressive laminectomy followed by PLIF (n=30; mean age 53.5 years), PLF (n=39; mean age 52.3 years), or ILP (n=34; mean age 55.0 years). All the patients had segmental instability due to grade I degenerative spondylolisthesis at L_{4-5}. Radiographically, we measured facet angles, transverse articular dimension, disc height, the angle of displacement in flexion, and the percent of slippage. Clinical outcomes were evaluated according to the Macnab criteria. The mean follow-up periods were 36 months, 35 months, and 22 months in the PLIF, PLF, and ILP groups, respectively.

Results: The average duration of anesthesia, the length of the incision, the amount of blood loss, and the length of hospital stay were significantly more favorable in the ILP group. The clinical success (excellent or good) rate was 76.7% in the PLIF group, 82.0% in the PLF group, and 85.3% in the ILP group (p=0.67). No neurological complications, infections, or device failure were encountered in the ILP group. However, deep wound infections (n=2), major neurological complications (n=3), newly developed degenerative spondylolisthesis (n=1), and mortality due to surgery-associated complications (n=1) were seen in the PLIF group. Device failure developed in four patients in the PLF group. Successful outcomes following ILP were significantly correlated with a facet angle <51.88°, disc height <9.38 mm, a decrease ≥50% in the slippage rate, and fewer vacuum phenomena.

Conclusion: Our data show that ILP is a safe and effective procedure in the treatment of grade I degenerative spondylolisthesis.

Key words: Joint instability; lumbar vertebrae/surgery/radiography; spinal stenosis/surgery; spondylolisthesis/ surgery.

Amaç: İnterspinöz ligamentoplasti (ILP) hafif-orta dereceli dejeneratif lomber instabilitenin düzeltilmesinde nispeten yeni bir yöntemdir. Bu çalışmada ILP, posterior lomber interbody füzyon (PLIF) ve posterolateral füzyonun (PLF) sonuçları karşılaştırıldı ve ILP başarısını etkileyen radyografik faktörler değerlendirildi.

Hastalar ve yöntemler: Çalışmada, dekompresif laminektomiden sonra PLIF (n=30; ort. yaş 53.5), PLF (n=39; ort. yaş 52.3) ve ILP (n=34; ort. yaş 55.0) uygulanan 103 hasta geriye dönük olarak değerlendirildi. Tüm hastalarda L_{4-5} düzeyinde derece I dejeneratif spondilolistesise bağlı segmental instabilite vardı. Ameliyat öncesi ve sonrası radyografilerde faset açıları, transvers artiküler boyutu, disk yüksekliği, fleksiyonda deplasman açısı ve kayma oranı ölçüldü. Klinik sonuçlar Macnab ölçütlerine göre değerlendirildi. Ortalama izlem süresi PLIF, PLF ve ILP gruplarında sırasıyla 36 ay, 35 ay ve 22 ay idi.

Bulgular: Ortalama anestezi süresi, insizyon uzunluğu, kan kaybı miktarı ve hastanede kalma süresi ILP grubunda anlamlı derecede düşük bulundu. Klinik başarı (mükemmeel ve iyi) oranları PLIF, PLF ve ILP gruplarında sırasıyla %76.7, %82.0 ve %85.3 idi (p=0.67). Nörolojik komplikasyon, enfeksiyon veya enstrüman başarısızlığı ILP grubunda görülmezken, PLIF grubunda derin yara enfeksiyonu (n=2), önemli nörolojik komplikasyon (n=3), yeni dejeneratif spondilolistesis gelişimi (n=1) ve cerrahi ile ilgili komplikasyonlara bağlı ölüm (n=1); PLF grubunda ise dört olguda enstrüman başarısızlığı görüldü. İnterspinöz ligamentoplasti ile alınan başarılı sonuçların, 51.88 dereceden küçük faset açısı, 9.38 mm'den düşük disk yüksekliği, kayma oranında ≥50% azalma ve daha az vakum anormalliği ile anlamlı derecede ilişkili olduğu saptandı.

Sonuç: İnterspinöz ligamentoplasti, derece I dejeneratif spondilolistesis tedavisinde güvenli ve etkin bir girişimdir.

Anahtar sözcükler: Eklem instabilitesi; lomber vertebra/cerrahi/ radyografi; spinal stenosis/cerrahi; spondilolistesis/cerrahi.

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• *This work was supported by a grant from the Wooridul Spine Foundation.*

Degenerative spondylolisthesis with spinal stenosis is a common cause of chronic back pain and neurogenic intermittent claudication (NIC). Surgical treatment of degenerative spondylolisthesis with spinal stenosis has evolved from decompressive laminectomy alone to laminectomy and fusion with or without posterior instrumentation. Posterolateral fusion (PLF) with pedicle screw fusion has shown a more favorable outcome than has PLF alone.[1-4] Posterior lumbar interbody fusion (PLIF) with pedicle screw fixation, markedly increases the stiffness of the fused segment, and thus, is associated with better clinical outcomes.[5-7] However, there are many reports on the complications associated with fusion surgery with posterior instrumentation.

Interspinous ligamentoplasty (ILP) is a new concept which provides a dynamic stabilization of degenerative lumbar instability.[8] In this study, we compared the clinical outcomes of ILP, PLIF, and PLF. We also investigated radiological prognostic factors that might have influence on successful outcomes of ILP.

PATIENTS AND METHODS

The study included 103 patients who underwent decompressive laminectomy followed by one of the three stabilization procedures from January 1991 to December 1995. All the patients presented with neurological claudication and chronic back pain due to grade I degenerative spondylolisthesis at L_{4-5} with spinal stenosis, which did not respond to conservative treatment for six months. Those who had any previous spinal surgery were excluded. Of the study group, 30 patients underwent PLIF, 39 patients underwent PLF, and 34 patients underwent ILP. The demographic and operative data of all the patients are summarized in Table I.

In all the groups, surgical procedures were performed through the midline approach. In the PLIF and PLF groups, the incisions were made from the lower lamina of L_3 to that of L_5. These procedures required a subtotal decompressive laminectomy and bilateral foraminotomy (including medial facetectomy), followed by PLIF or PLF using autogenous iliac bone grafts with pedicle screw fixation. In the ILP group, only bilateral partial laminectomy with foraminotomy was performed to preserve the spinous process, the supraspinous and interspinous ligaments, and the facet joint. In the ILP procedure, the two spinous processes of L_4 and L_5 were tied together like the figure "8" with a 40 cm polyester braid artificial ligament (Liganove™, Cousin Biotech, Wervicq-Sud, France) while preserving the space between the base of the spinous processes (Fig. 1). To complete ILP, the artificial ligament was tightly tied after restoring lordosis by bending the operating table. The artificial ligament was tied near the center of

TABLE I

The demographic and operative data of the study group

	Posterior lumbar interbody fusion	Posterolateral fusion	Interspinous ligamentoplasty
Age (years)	53.53±6.6	52.33±6.6	55.03±8.5
Gender (Male / Female)	6 / 24	6 / 33	4 / 30
Duration of symptoms (months)	72.73±48.3	71.89±53.7	65.09±48.5
Preoperative displacement (%)	14.82±5.1	16.22±4.7	15.28±7.3
Preoperative transverse articular dimension (mm)	18.93±1.4	19.17±1.3	18.12±1.1
Osteoporosis (n / %)	6 / 20	5 / 12.82	15 / 44.11
Preoperative facet angle (°)	56.36±10.7	54.36±10.7	46.62±12.8
Preoperative disc height (mm)	10.36±1.7	9.69±2.1	8.44±2.5
Presence of traction spurs (n / %)	28 / 93	35 / 90	31 / 90
Duration of anesthesia (min)	359.33±44.32	298.46±37.45	117.06±24.18
Incision length (cm)	14.17±1.31	14.15±1.09	5.24±0.7
Intraoperative blood loss (ml)	1123.0±121.14	1034.6±96.07	542.7±50.94
Postoperative blood loss (ml)	302.66±75.74	296.66±73.92	No drain
Hospital stay (days)	18.70±1.85	19.15±1.77	4.59±0.92

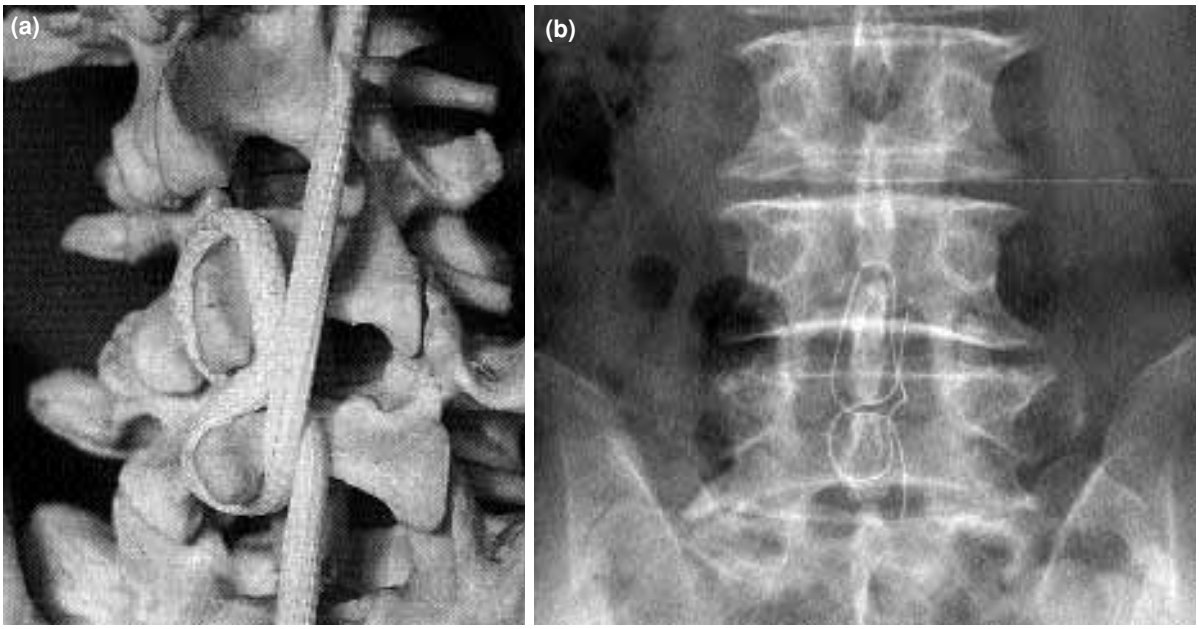

Fig. 1. (a) The tying method of the artificial ligament and **(b)** its appearance on an X-ray image. The two spinous processes of L_4 and L_5 are tied together like the figure "8" with a 40-cm polyester braid artificial ligament.

the figure "8" using 2-0 nylon so that the knot of the ligament could serve as an interspinous spacer. Preoperative instability was corrected with the use of the artificial ligament (Fig. 2).

To evaluate the patients, we measured facet angles, transverse articular dimension, disc height, and the angle of displacement in flexion using the method proposed by Dupuis et al.,[9] and the percent of slippage using the Marique-Taillard method[10,11] on preoperative and postoperative radiographs (Fig. 3). In fusion cases, the success of bony fusion was assessed by a radiologist on both plain and dynamic bending radiographs according to the criteria proposed by Kant et al.[12] The outcomes were evaluated according to the Macnab criteria.[13]

The mean follow-up period was 36 months (range 21 to 68 months) for the PLIF group, 35 months (range 15 to 57) for the PLF group, and 22 months (range 15 to 27) for the ILP group. Statistical analyses were made using the chi-square test, ANOVA analysis, and the Fisher's exact test. A p value of less than 0.05 was regarded as significant.

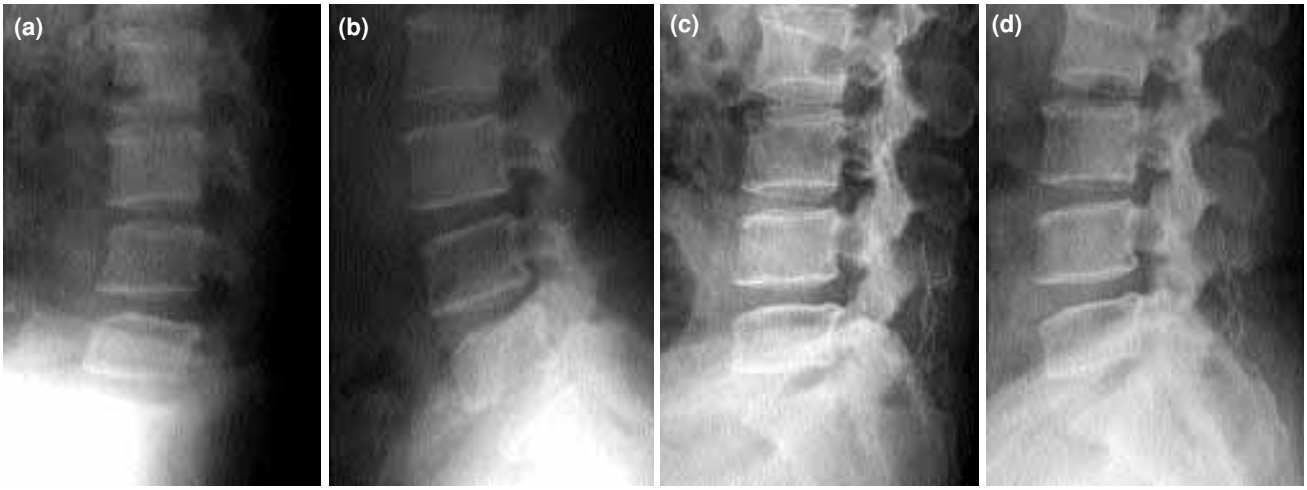

Fig. 2. Comparison of **(a and b)** preoperative and **(c and d)** postoperative dynamic views of a patient who underwent interspinous ligamentoplasty.

TABLE II

Comparison of the clinical outcomes according to the Macnab criteria[13]

Outcomes	Posterior lumbar interbody fusion (n=30)		Posterolateral fusion (n=39)		Interspinous ligamentoplasty (n=34)		Macnab criteria
	n	%	n	%	n	%	
Excellent	3	10.0	8	20.5	4	11.8	There is no back or leg pain and the patient returns back to full activity and employment within six months of surgery.
Good	20	66.7	24	61.5	25	73.5	There is minimal pain with no significant handicap.
Fair	5	16.7	5	12.8	4	11.8	There is a definite improvement following surgery, but with restriction of activity; analgesics are required.
Poor	2	6.7	2	5.1	1	2.9	There is no improvement after surgery.

RESULTS

The average duration of anesthesia, the length of the incision, the amount of blood loss, and the length of hospital stay were significantly more favorable in the ILP group than those found in the PLIF and PLF groups (Table I). According to the Macnab criteria, the success (excellent or good) rate was 76.7% in the PLIF group, 82.0% in the PLF group, and 85.3% in the ILP group (Table II). Although no significant differences existed between the three groups (p=0.67), the ILP group showed the highest success rate.

In the PLIF group, there were two cases of deep wound infections that required debridement and irrigation with antibiotics; three cases of major neurological complications including foot drop and paresthesia of the leg; newly developed degenerative spondylolisthesis in one case, that occurred proximal to the L_4 and L_5 fusion site. One patient in this group died of surgery-associated complications. In the PLF group, hardware failure (pedicle screw fracture) occurred in four patients. In the ILP group, however, there were no neurological complications, infections, or device failure.

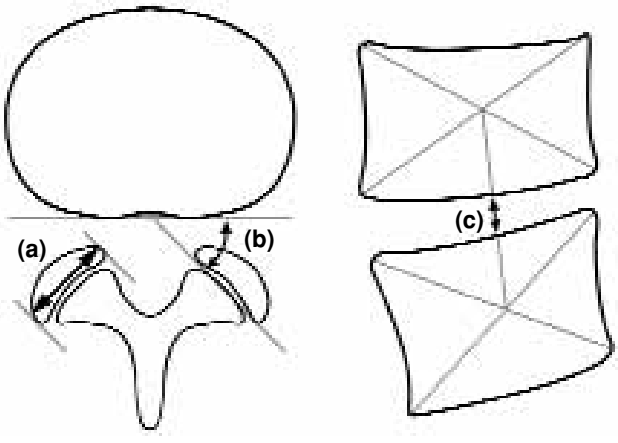

Fig. 3. Measurement of (a) transverse articular dimension, (b) facet angle, and (c) the disc height.

The overall mean values of facet angle, disc height, and the rate of decrease in transverse articular dimension in 103 patients were 51.88 degrees, 9.38 mm, and 21.27%, respectively. Correlations between the clinical outcomes and radiologic findings are summarized in Table III.

A disc height of less than 9.38 mm was correlated with a favorable outcome. In the ILP group, 23 patients with a disc height of less than 9.38 mm were rated as having an excellent or good outcome; in contrast, five of eleven patients with a disc height of more than 9.38 mm had an unsuccessful (fair or poor) outcome (p=0.0005).

Facet morphology was found as another significant factor in the outcomes of ILP. All the patients presenting with a vacuum facet alone (without vacuum disc or facet destruction) had a successful outcome. The presence of both a vacuum disc and a destructed facet was associated with an unsuccessful outcome in all the patients, showing the need for fusion with a pedicle screw in such cases (p=0.0092).

The alignment of the facet joint also played an important role in the outcomes of ILP. A more sagittal alignment (above 51.88 degrees) resulted in an unsuccessful outcome in 42.8% (3/7); however, a coronal alignment (below 51.88 degrees)

TABLE III

Correlations between clinical outcomes and radiologic findings

	Posterior lumbar interbody fusion (n=30)		Posterolateral fusion (n=39)		Interspinous ligamentoplasty (n=34)	
Radiological findings	Successful	Unsuccessful	Successful	Unsuccessful	Successful	Unsuccessful
Facet angle (°)						
<51.88	13	0	21	0	25	2
>51.88	10	7	11	7	4	3
p value	p=0.0082		p=0.0016		p=0.0183	
Disc height (mm)						
<9.38	6	0	13	0	23	0
>9.38	17	7	7	19	6	5
p value	p=0.1038		p=0.0389		p=0.0005	
Vacuum phenomena						
Vacuum facet*	3	1	4	1	19	0
VD	8	2	15	1	5	0
VVD	12	4	13	5	5	5
p value	p=0.9545		p=0.2616		p=0.0092	
Decrease in the rate of slippage(%)**						
0	0	3	0	4	0	0
<50	0	2	1	1	10	4
≥50	23	2	31	2	19	1
p value	p<0.0001		p<0.0001		p=0.0128	
Decrease in the rate of transverse articular dimension (%)***						
<21.27	13	2	18	1	9	2
>21.27	10	5	14	6	20	3
p value	p=0.1953		p=0.0442		p=0.6923	

*: Vacuum facet is the gap between the inferior and superior articular facet as seen on an axial CT scan; VD: Vacuum facet and vacuum disc; VVD: Vacuum facet, vacuum disc, and destructed facet; **: Decrease in the rate of slippage = [(Preoperative translation - Postoperative translation) / Preoperative translation]; x 100; ***: Decrease in the rate of transverse articular dimension after surgery = [(Preoperative transverse dimension - Postoperative transverse dimension)] / Preoperative transverse dimension x 100.

resulted in a successful outcome in 92.6% (25/27) (p=0.0183).

Progressive postoperative slippage occurred in three patients in the PLIF group and in four patients in the PLF group, all of whom had unsuccessful outcomes. There was no progression in either a frontal or sagittal deformity in the ILP group.

DISCUSSION

In our study, ILP showed better clinical outcomes than did PLF or PLIF in patients with grade I degenerative spondylolisthesis with spinal stenosis. Both PLF and PLIF have been widely used to treat spinal instability in patients suffering from isthmic spondylolisthesis, grade II or higher degenerative spondylolisthesis, or in those who require radical decompression and discectomy.[9,14] However, compared with ILP, either PLIF of PLF represents a more invasive procedure in mild degenerative spondylolisthesis with spinal stenosis. Because the possibility of a subsequent operation exists following any kind of surgery, selection should be made in favor of the least invasive surgical option that is known to yield the highest successful outcome.

Voydeville[15] studied the biomechanics of a similar type of ligamentoplasty *in vitro* on six functional human L_4-L_5 spinal units. He reported that a flexible and soft type of stabilization with ligamen-

toplasty caused limitation in flexion-extension, axial rotation, and lateral flexion. In addition, ligamentoplasty corrected the narrowing of the spinal canal and stabilized the motion segment, providing the canal an appropriate width.[15,16]

This process was also assessed by Papp et al.[16] who studied the biomechanical effects of a flexible polyester artificial ligament. Although they used a hook system, the material used to construct the ligament was identical. They found that the ligament reinforced the posterior structure of the lumbar motion segment, thus creating a phenomena referred as "facet locking". Even though the material used to construct the ligament is soft and subject to flexion with the movement of the spine, it still restricts 80% of the patient's motion and provides great stability through this type of locking and through the preservation of the body's own stabilization structures.

The type of ILP outlined in this study emphasizes the preservation of the stabilization components.[17,18] It preserves the spinous process, the supraspinous, interspinous, and posterior longitudinal ligaments, and the posterior annulus.[6] This small, selective facetectomy restores the spinal canal to its proper size without compromising the stability of the segment.[18] Because ILP surgery only removes 21.27% of the facet, a pedicle screw or fusion is not necessary for stabilization.

Interspinous ligamentoplasty was originally proposed by Senegas et al.[8] as a way to simplify and shorten the stabilization procedure. Fassio et al.[19] performed ILP to counteract chronic instability due to degenerative disc disease and encountered no complications. Another study found that the advantages of not using an internal fixation device included a shorter operating time, less potential to induce neurological impairment, and a decreased overall infection rate.[3]

Biomechanically, in this study, ILP restored lumbar lordosis and the knot of the ligament served as an interspinous spacer increasing the disc unloading. The goal of this dynamic stabilization is to stabilize the motion segment through preserving motion. Therefore, this procedure is ideal for elderly patients and for those who are generally in poor health, in whom potentially problematic surgical procedures such as PLIF or PLF should be avoided. Fusion should be strictly narrowed among older patients with degenerative spondylolisthesis .[20]

Various factors affect the result of ligamentoplasty. A more sagittal alignment of the facet joint is associated with reduced coronal dimension that would further increase postoperative anterior slippage.[21-23]

In this study, the average duration of anesthesia, the size of the incision, the amount of blood loss, and the length of hospital stay were significantly more favorable in the ILP group than those found in the PLIF and PLF groups. In the ILP group, posterior dissection is merely to expose the two spinous processes and medial facets of L_4 and L_5. However, in fusion groups, dissection should be extended more laterally, which means more injury to back muscles. It is important to note that the patients in this study had longer periods of hospital stay following surgery compared to their counterparts in the United States or several other countries because the health care system in Korea makes hospital care quite affordable to most patients. Because of the relatively low cost of hospital stay, Korean patients usually prefer to go home after having their stitches removed.

In conclusion, ILP is safer and easier than fusion operations in the treatment of grade I degenerative spondylolisthesis with spinal stenosis. Although the higher success rate of ILP was not found significant in our study, it is apparently more advantageous over PLIF and PLF in terms of less invasiveness and a lower complication rate.

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