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Changes in facets and adjacent discs following lumbar artificial disc replacement arthroplasty

Lomber disk replasmanı artroplastisinden sonra faset ve komşu disklerde meydana gelen değişiklikler

Soo-Taek Lim, M.D.,[1] Won-Joong Kim, M.D.,[1] Sang-Ho Lee, M.D., PhD.,[2]
Sang-Hyuck Min, M.D.,[1] Byungjoo Jung, M.D.[2]

Departments of [1]Orthopedic Surgery, [2]Neurosurgery, Wooridul Spine Hospital, Seoul, Korea

Objectives: This prospective study was designed to determine the changes in the adjacent discs and the facet joints at the spinal segments following artificial disc replacement (ADR).

Patients and methods: Twenty-seven patients (7 men, 20 women; mean age 47.2 years; range 29-69 years) were treated with ADR for symptomatic degenerative disease (L_{4-5} in 10, L_5-S_1 in 8, L_{3-5} in 2, and L_{4-5}-S_1 in 7 patients). Radiologic evaluations were based on dynamic flexion-extension radiographs and magnetic resonance (MR) images obtained preoperatively and postoperatively at the end of a year. Disc degeneration was assessed on T_2-weighted midsagittal MR images of upper (n=27) and lower (n=12) adjacent levels according to the classification by Pfirrmann et al. Osteoarthritic changes (cartilage degeneration, subchondral sclerosis and osteophytes) in the facet joints at the replaced level were rated on T_2-weighted MR axial images according to the classification by Grogan et al. Flexion-extension range of motion (ROM) was measured on radiographs by the Cobb method. Clinical results were evaluated by the Oswestry Disability Index (ODI). The mean follow-up period was 14.6 months (range 12 to 19 months).

Results: No surgical failures or complications were encountered. The mean ODI score improved significantly at the last follow-up ($p<0.01$). Of 27 superior adjacent discs, four improved and 23 remained unchanged; of 12 lower adjacent discs, one improved, and 11 did not change. None of the adjacent discs showed worsening. Many of the adjacent discs became more hydrated. The high-intensity zone disappeared in three adjacent segments. The facet joints and the adjacent facets showed neither improvement nor aggravation. Flexion-extension ROM showed significant improvement at two operated levels (L_{4-5} and L_5-S_1; $p<0.01$).

Conclusion: Early results of ARD seem to be promising for the prevention of adjacent segment degeneration.

Key words: Intervertebral disk displacement/surgery; lumbar vertebrae/surgery/radiography; neurodegenerative diseases/diagnosis; prostheses and implants; range of motion, articular; spinal fusion/methods/adverse effects.

Amaç: Bu prospektif çalışmada, lomber disk replasmanından (LDR) sonra komşu disklerde ve spinal segmentlerdeki faset eklemlerde meydana gelen değişiklikler araştırıldı.

Hastalar ve yöntemler: Yirmi yedi olgu (7 erkek, 20 kadın; ort. yaş 47.2; dağılım 29-69) semptomatik dejeneratif lomber hastalık (10 L_{4-5}, 8 L_5-S_1, 2 L_{3-5}, 7 L_{4-5}-S_1) nedeniyle LDR ile tedavi edildi. Radyolojik değerlendirmelerde ameliyat öncesinde ve ameliyat sonrası birinci yılda çekilen dinamik fleksiyon-ektansiyon radyografileri ve manyetik rezonans (MR) görüntüleri kullanıldı. Üst (n=27) ve alt (n=12) komşu düzeylerdeki disk dejenerasyonu, Pfirrmann ve ark.nın sınıflamasına göre, T_2-ağırlıklı midsagittal MR görüntüleri ile incelendi. Replasman uygulanan düzeydeki faset eklemlerdeki osteoartritik değişiklikler (kıkırdak dejenerasyonu, subkondral skleroz, osteofit oluşumu) T_2-ağırlıklı aksiyel MR görüntülerde Grogan ve ark.nın sınıflamasına göre incelendi. Fleksiyon-ekstansiyon hareket açıklığı radyografiler üzerinde Cobb yöntemiyle hesaplandı. Klinik sonuçlar Oswestry Özürlülük İndeksi (OÖİ) ile değerlendirildi. Ortalama izlem süresi 14.6 ay (dağılım 12-19 ay) idi.

Bulgular: Hiçbir olguda cerrahi başarısızlık veya komplikasyonla karşılaşılmadı. Son kontrolde, ortalama OÖİ skoru anlamlı derecede düzelme gösterdi ($p<0.01$). Yirmi yedi üst komşu diskin dördünde düzelme görülürken, 23'ünde değişiklik olmadı; 12 alt komşu diskin birinde iyileşme gözlenirken, 11'inde değişme olmadı. Komşu disklerin hiçbirinde kötüleşme görülmedi; birçoğunun sıvı içeriği arttı. Üç komşu segmentte yüksek yoğunluklu bölge kayboldu. Faset eklemlerde ve yakın fasetlerde değişim gözlenmedi. Fleksiyon-ekstansiyon hareket açıklığı ameliyat edilen iki düzeyde anlamlı artış gösterdi (L_{4-5} ve L_5-S_1; $p<0.01$).

Sonuç: Erken sonuçlarımız, LDR'nin komşu segment dejenerasyonunu önlemede ümit verici bir yöntem olduğunu gösterdi.

Anahtar sözcükler: İntervertebral disk deplasmanı/cerrahi; lomber vertebra/cerrahi/radyografi; nörodejeneratif hastalık/tanı; protez ve implant; hareket açıklığı, artiküler; spinal füzyon/yöntem/yan etki.

- *Correspondence: Won-Joon Kim, MD. Department of Orthopedic Surgery, Wooridul Spine Hospital, 47-4 Chungdam-Dong Gangnam-Gu, Seoul 135-100, Korea. Tel: +00 - 82 - 2 - 513 8151 Fax: +00 - 82 - 2 - 513 8146 e-mail: frangie@wooridul.co.kr*
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Degeneration that develops at motion segments above and below the fused spinal segments is known as adjacent segment disease or transitional zone syndrome.[1-3] Adjacent segment disease includes degeneration (loss of disc height, disc space narrowing), spondylolisthesis, instability, herniated nucleus pulposus, stenosis, and degeneration of the facet joint.[4]

Various clinical studies has shown a strong tendency of the adjacent motion segments above and below the fused spine towards accelerated degeneration. Spinal fusions result in increased stress and motion at the adjacent segments. This may give rise to clinical symptoms and late failures of the adjacent segment.[5-8] To avoid adverse effects of spinal fusion on adjacent segments, various nonfusion techniques have been developed, including nonfusion technique, ligamentoplasties, prosthetic disc nucleus (PDN) surgery, and artificial disc replacement (ADR).[6-12] This prospective study was designed to investigate the changes in the adjacent discs and the facet joints at the spinal segments following ADR.

PATIENTS AND METHODS

Between October 2002 and April 2003, 27 patients (7 men, 20 women; mean age 47.2 years; range 29-69 years) were treated with ADR for symptomatic degenerative disease of the lumbar spine. The main presenting symptoms were neurogenic claudication (n=9), radiculopathy (n=8), severe back pain without neurologic compromise (degenerative disc disease) (n=4), and degenerative flatback with back pain (n=6). All the patients were unresponsive to a prolonged conservative treatment for more than six months. Provocative discography was performed in all the patients before surgery at suspicious disc level. Contraindications for ADR included a target level higher than L_{1-2}, and the presence of a vertebral body fracture, severe facet joint degeneration, infection, significant spinal malalignment or disc space tilting and/or wedging in the coronal and sagittal planes.

Clinical evaluation

The protocol included a detailed history of the symptoms, physical examination, and Oswestry Disability Index (ODI) score before operation and with each radiologic study from the first postoperative month. The mean follow-up period was 14.6 months (range 12 to 19 months).

Radiologic evaluation

All the patients were evaluated by dynamic flexion-extension radiographs, magnetic resonance imaging (MRI), and computed topography. Standing dynamic radiographs were obtained on the first postoperative day, and at the end of three and six months; MRI scans and dynamic x-rays were obtained at the end of a year. T_2-weighted midsagittal MR images were used to assess disc degeneration at upper and lower adjacent levels according to the classification proposed by Pfirrmann et al.[13] The grading system for the assessment for lumbar disc degeneration is summarized in Table I.

TABLE I

The grading system for the assessment for lumbar disc degeneration[13]

Grade	MRI findings
I	The structure of the disc is homogeneous, with a bright hyperintense white signal intensity and a normal disc height.
II	The structure of the disc is inhomogeneous, with a hyperintense white signal. Distinction between the nucleus and annulus is clear, and the disc height is normal, with or without horizontal gray bands.
III	The structure of the disc is inhomogeneous, with an intermediate gray signal intensity. Distinction between the nucleus and annulus is unclear, and the disc height is normal or slightly decreased.
IV	The structure of the disc is inhomogeneous, with hypointense dark gray signal intensity. Distinction between the nucleus and annulus is lost, and the disc height is normal or moderately decreased.
V	The structure of the disc is inhomogeneous, with a hypointense black signal intensity. Distinction between the nucleus and annulus is lost, and the disc space is collapsed.

TABLE II

The grading systems for cartilage degeneration, subchondral sclerosis and osteophytes[14]

	Grade	MRI findings
Cartilage degeneration	I	Uniformly thick cartilage covers the articular surfaces completely.
	II	Cartilage covers the entire surface of the articular processes, but erosion to the irregular region is evident.
	III	Cartilage incompletely covers the articular surfaces, with regions of the underlying bone exposed to the joint.
	IV	Cartilage is absent except for the trace on the articular surfaces.
Subchondral sclerosis	I	Articular processes have a thin layer of cortical bone.
	II	Cortical bone of the articular process is focally thickened.
	III	The thickened cortical bone covers less than half of the articular processes.
	IV	Dense cortical bone covers more than half of the articular processes.
Osteophytes	I	No osteophyte.
	II	Possible or small osteophyte.
	III	Definite and moderate osteophyte.
	IV	Large osteophyte.

Osteoarthritic changes in the facet joints of the replaced level were scored into four grades according to the classification proposed by Grogan et al.[14] in terms of cartilage degeneration, subchondral sclerosis and osteophytes on T_2-weighted MRI axial images (Table II). Flexion and extension range of motion (ROM) was measured on radiographs by the Cobb method preoperatively and postoperatively at the end of a year.

Surgical technique and implants

For levels L_{3-4} and L_{4-5}, the ADR was carried out using the left retroperitoneal approach via an anterior midline incision, with the patient in the supine position. For L_5-S_1, a right retroperitoneal approach via an anterior midline incision was used to reduce the risk for injury to the superior hypogastric plexus. For L_{4-5}-S_1 level, the left retroperitoneal approach was used. Artificial disc replacement was carried out in 37 levels, where Prodisc-L Implant (B. Brown, Germany) was used in 25 levels, and SB Charité III implants (Link, Germany) were used in 12 levels.

Data analysis

Statistical analyses were performed using the SPSS 11.0 (SPSS Inc., Chicago, IL, USA). Preoperative and postoperative ODI scores were analyzed using the paired samples t-test. The differences between preoperative and postoperative extension and flexion ROM at each operated level were analyzed using the Wilcoxon signed-ranks test.

RESULTS

Clinical results

There were no surgical failures or complications that required reoperation. No implant-related failure including implant dislocation or subsidence occurred within a-year follow-up. Patients with neurologic symptoms showed improvement from the immediate postoperative period, which maintained throughout the follow-up period. The mean ODI score improved from a preoperative score of 65% (range 44% to 82%) to 22%, 19%, 16%, and 15% (range 0% to 60%) at the end of the first month, three months, six months, and at the last follow-up, respectively. The improvement in ODI scores was statistically significant ($p<0.01$).

Radiological results

Artificial disc replacement was performed in L_{4-5} in 10 patients, L_5-S_1 in eight patients, L_{3-5} in two patients, and L_{4-5}-S_1 in seven patients. Adjacent disc degeneration was rated as grade II (n=3), grade III (n=6), grade IV (n=18) at the proximal adjacent segments, and grade II (n=4), grade III (n=5), and grade IV (n=3) at the distal adjacent segments.

At the end of a year postoperatively, of 27 superior adjacent discs, four improved and 23 remained unchanged; worsening was not observed (Fig. 1). The improvement was in the hydration of the adjacent discs, without any

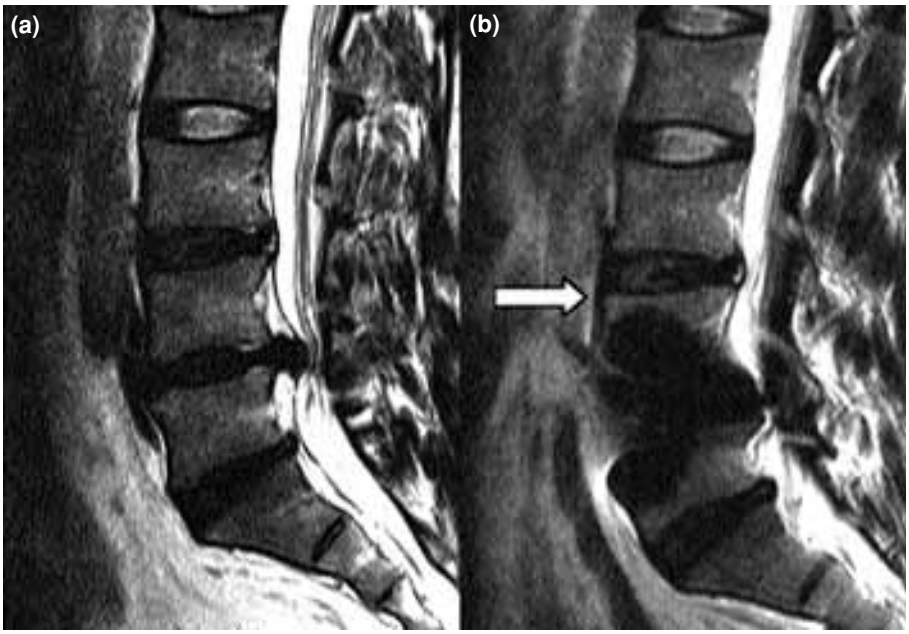

Fig. 1. A 36-year-old male patient with degenerative disc disease. Artificial disc replacement was performed at the L_{4-5} level. **(a)** Grade IV disc degeneration of the superior adjacent segment. **(b)** A year after surgery, improvement in the hydration of the disc was observed without any change in the grade (arrow).

change in the grade of degeneration. In two patients, the high-intensity zone (HIZ) disappeared (Fig. 2). Of 12 lower adjacent discs, one improved, and 11 did not change; worsening was not observed. The high-intensity zone disappeared in one of the lower adjacent segments. Many of the adjacent discs became more hydrated even though they maintained the grade.

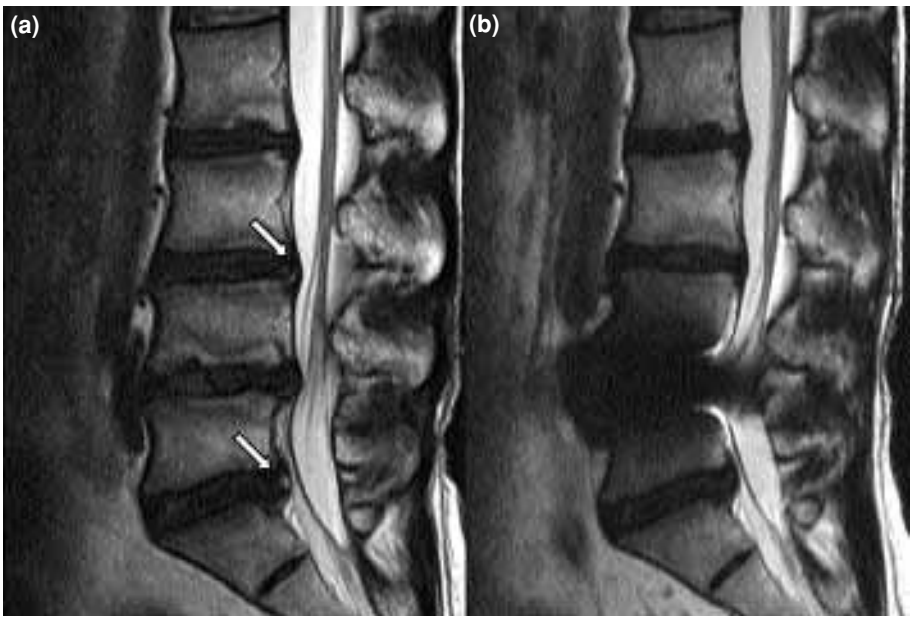

Fig. 2. A 29-year-old male patient with degenerative disc disease. Artificial disc replacement was performed at the L_{4-5} level. **(a)** He had high-intensity zones at the superior and inferior adjacent segments at the levels L_{3-4} and L_5-S_1 (arrow). **(b)** A year after surgery, the high-intensity zones disappeared at the superior and inferior adjacent segments.

TABLE III

Postoperative grades for cartilage degeneration, subchondral sclerosis and osteophytes

	Grade	No. of levels	%
Cartilage degeneration	I	25	67.6
	II	12	32.4
Subchondral sclerosis	I	14	37.8
	II	23	62.2
Osteophytes	I	16	43.2
	II	20	54.1
	III	1	2.7

The degree of postoperative cartilage degeneration, subchondral sclerosis, and osteophytes at the replaced levels are tabulated in Table III. The facet joints did not undergo any change with regard to cartilage degeneration, subchondral sclerosis, and osteophytes. Similarly, the adjacent facet joints showed neither improvement nor aggravation.

Comparison of preoperative and final degrees of flexion-extension ROM showed significant improvement at two operated levels (L4-5 and L5-S1; $p<0.01$) (Table IV).

DISCUSSION

Adjacent segment degeneration (ASD) following spinal fusion is of much concern and accounts for a substantial percentage of revision surgeries. Numerous biomechanical studies have demonstrated that the fusion process significantly increases the amount of stress at the adjacent segments. Although the development of degeneration may be considered a part of normal aging and degenerative processes, this phenomenon appears to be at least partly influenced by altered stresses associated with lumbar fusion. The reported prevalence of degeneration at the adjacent segments range from 5% to 43%.[7]

TABLE IV

Comparison between preoperative and final degrees of flexion-extension range of motion (ROM)

	Preoperative		Final	
Levels	ROM (°)	Range	ROM (°)	Range
L_{3-4}	4.8±1.3	3.7-6.2	13.2±5.1	9.4-19.0
L_{4-5}	8.1±4.5	1.0-19.0	14.0±4.8	5.0-22.0
L_5-S_1	6.9±3.7	3.1-16.5	11.9±3.9	7.0-18.7

In a homogeneous group of patients operated on during a 14-year period for degenerative conditions of the lumbar spine, Gillet[4] reported that 41% of the patients developed adjacent motion segment alterations including dehydration of the disc visible only on MR images; disc space narrowing, disc space vacuum, osteophyte formation; appearance of or increase in degenerative retrolisthesis, antelisthesis or rotary dislocations; spinal stenosis due to hypertrophy of the posterior facets; bulging of the disks or the ligaments, and instability with static or dynamic malalignment of the spine. In addition, 20% of the patients required a secondary operation for extension of the fusion. However, the prevalence of subsequent lumbar surgeries performed for the treatment of this degeneration was found lower (range 2% to 15%).[7]

The authors postulated that preserving motion segments above and below the adjacent segments would contribute to a decrease in the incidence of ASD. Artificial disc replacement offers mobile stability, enables a physiologic reconstruction of the subject segment, and is considered a promising method to prevent the development of precocious degeneration of segments adjacent to the index level.[9] Kumar et al.[15] compared the fate of the transitional segments in patients who had undergone surgery for degenerative disc disease with or without fusion. Narrowing of the disc space was observed in 35.7% of the fusion group as opposed to 18.5% in the decompression group, with instability rates being 18.5% and 7.4%, respectively. Gillet[4] proposed that reliable arthroplasty procedures be developed in order to decrease the occurrence of ASD. Huang et al.[16] assessed long-term (8.7 years follow-up) flexion-extension ROM of patients following the Prodisc total disc replacement. They found that 66% of the patients had more than 2 degrees of ROM, and that the mean ROM of prosthesis below a degenerated junctional disc was 1.6 degrees compared to 4.7 degrees below the normal junctional disc. They concluded that the ROM of disc prosthesis was correlated with the development of junctional degeneration.

In our study, postoperative improvement in ODI scores was statistically significant. McAfee et

al.[17] evaluated the clinical results of SB Charité disc replacement and BAK anterior interbody fusion and found significantly improved ODI scores in favor of the former.

This study showed increased hydration in adjacent segments; the superior adjacent disc improved in four patients, and the lower in one patient. This result was associated with decreased stresses on adjacent segments and the role of motion preservation to prevent further adjacent level degeneration. In addition, HIZ disappeared in two superior, and in one lower adjacent segments. Annular fissures with high signal intensity on MRI have been purported to be a reliable marker of active and clinically significant annular disc disruption.

Aprill and Bogduk[18] reported that the finding of an HIZ on MRI has a very high positive predictive value for discogenic pain as the cause of chronic low back pain. The prevalence of an HIZ in patients with low back pain was 59%, and HIZ was also documented in 24% of asymptomatic subjects. Saifuddin et al.[19] demonstrated that the development of HIZ and radial annular tears were apparent on axial loaded MRI images at the level of previous discography, whereas unloaded MRI images failed to show HIZ. This finding may imply that loss of HIZ at the adjacent segment results from decreased pressure at the junctional levels after ADR.

There was no change in the facets with respect to cartilage degeneration, subchondral sclerosis, and osteophytes. Primary degradation of the disc results in secondary changes in the facet joints and ligaments as a result of load shift from the disc to those structures. Degeneration of facet joints is seen in late stages of the disease. One year follow-up is too short to evaluate changes in the facet joints.

A limitation of this study is that the authors evaluated the adjacent segments that are only one level above and below ADR. Ghiselli et al.[7] reported adjacent level degeneration in 27.4% at the end of a follow-up period of 6.7 years after fusion. The adjacent levels in this series included segments up to two-level cephalad and caudad to the fusion and comparison between preoperative and postoperative radiographs showed significant degeneration at all the levels studied.[7]

In conclusion, early results of ARD are promising for the prevention of adjacent segment degeneration. The effect of ADR on the facets seems to be negligible. However, its long-term effect on adjacent segments and replaced facets merits further evaluations.

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