Artificial Disk Replacement Combined With Midlevel ACDF Versus Multilevel Fusion for Cervical Disk Disease Involving 3 Levels

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abstract

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The optimal surgical approach for cervical disk disease remains a matter of debate, especially for multilevel disease. The purpose of this study was to compare the results of 2 surgical strategies for cervical disk disease involving 3 levels: hybrid constructs, artificial disk replacement combined with midlevel anterior cervical discectomy and fusion (ACDF), and 3-level ACDF. The authors prospectively compared patients who had cervical disk disease involving 3 levels that was treated with hybrid constructs or with 3-level ACDF. Patients were asked to use the Neck Disability Index (NDI) to grade their pain intensity preoperatively and at routine postoperative intervals of 1, 3, 6, 12, and 24 months. Dynamic flexion and extension lateral cervical radiographs were obtained while in the standing position preoperatively and at the postoperative intervals. The angular range of motion for C2-C7 and the adjacent segments was measured using the Cobb method. Twenty-four patients were treated, 12 with hybrid constructs and 12 with 3-level ACDF.

Both groups had significant postoperative improvement in NDI scores and neck pain (P<.05). However, no significant difference was found between the groups (P>.05). The hybrid constructs group showed faster recovery of C2-C7 range of motion. Mean C2-C7 range of motion of the hybrid constructs group recovered to that of the preoperative value, but that of the 3-level ACDF group did not (P<.05). Range of motion of the superior and inferior adjacent segments showed significant differences between the 2 groups at 12 and 24 months postoperatively (P<.05). These findings suggest that the hybrid constructs is a safe and effective alternative for cervical disk disease involving 3 levels. The definite stabilization and maintained range of motion can be achieved right away, which can ensure a good preliminary clinical outcome.

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Figure: Pre- (A) and postoperative (B) anteroposterior radiographs of a patient who underwent artificial disk replacement combined with mid-level anterior cervical discectomy and fusion.
Recently, with advances in surgical techniques, artificial disk replacement has been widely accepted and used in the treatment of cervical disk disease. It maintains the functional motion of diseased segments, attenuates stress transmission of adjacent segments, and reduces adjacent segment degeneration.1-3 Previous studies have reported that the use of artificial disk replacement is associated with favorable clinical and radiological outcomes for 1- and 2-level cervical disk disease.2,4,5 Previously, the predominant surgical option for patients with multilevel disease was anterior cervical diskectomy and fusion (ACDF). However, this procedure notably impairs cervical motion and seriously compromises patients’ quality of life. Moreover, multilevel fusion is more likely to result in disk degeneration of the adjacent segments, challenging fusion, and frequent pseudarthrosis.6-11

In theory, when fewer segments are fused, less compensatory activity occurs in the adjacent segments, and the likelihood of adjacent segment degeneration decreases. To date, few reports exist on multilevel cervical artificial disk replacement. Short-term follow-up found no implant migration or other complications.12,13 However, the biomechanical effect of artificial disk replacement involving 3 or more segments remains poorly understood, and its clinical effect has not yet been examined in prospective controlled trials. Moreover, artificial disk replacement is associated with several problems, including difficult implantation and prosthesis-related complications.14 Meanwhile, its surgical indications are still being defined, and the surgery is available only for select patients, mainly young patients with simple multilevel cervical disk disease.

Artificial disk replacement combined with fusion considerably reduces possible complications from multilevel artificial disk replacement while largely preserving cervical motion and avoiding the drawbacks of multilevel fusion.15 It may become a supplemental procedure for the treatment of multilevel cervical disk disease. Currently, little information is available concerning the efficacy of artificial disk replacement combined with fusion for the treatment of multilevel cervical disk disease and the effect of the combination procedure on adjacent segments. The current study was designed to compare hybrid constructs, artificial disk replacement combined with midlevel ACDF, and 3-level ACDF for the treatment of cervical disk disease involving 3 cervical levels.

**MATERIALS AND METHODS**

Approval was obtained from the authors’ institutional review board prior to beginning this study. Twenty-four patients (15 men and 9 women) who were seen between October 2007 and October 2009 for cervical disk disease involving 3 contiguous segments that was unresponive to 6 weeks of conservative treatment preoperatively were included in the study, excluding those with obvious cervical instability, osteoporosis, and inflammatory disorder. All patients were informed about the purpose of and their inclusion in the current study and provided written, informed consent that was signed at least 24 hours preoperatively.

Twenty-four patients were divided into the study group (hybrid constructs) or control (3-level ACDF) group using randomization based on hospital number: patients from an odd-numbered hospital comprised the study group and patients from even-numbered hospitals comprised the control group. Twelve patients received artificial disk replacement combined with midlevel ACDF, whereas 12 patients were treated with 3-level ACDF. Surgery was performed by 3 surgeons (K.L., L.D., D.Z.), and patients followed a standardized postoperative rehabilitation program. All data were collected prospectively (Table 1).

**SURGICAL TECHNIQUE**

A standard Smith-Robinson approach was used to expose the treatment levels in all patients.16 The surgical technique was the same in both groups. The cartilaginous endplate was removed with a curette, and
caution was taken not to damage the bony endplate. The uncovertebral joints were left intact. The control group underwent arthrodesis with an autogenous iliac-crest graft and a cervical plate system (Synthes Spine, West Chester, Pennsylvania). The hybrid constructs group had an arthroplasty using ProDisc-C (Synthes Spine) combined with midlevel fusion with cervical interbody fusion cage or ZERO-P (Synthes Spine) filled with iliac bone (Figures 1, 2).

**Clinical Evaluation**

Clinical evaluation was based on the Neck Disability Index (NDI) to evaluate the ability of patients to participate in activities of daily living. The results were transformed to a percentage score ranging from 0%, indicating no disability, to 100%, indicating maximum disability. The visual analog scale (VAS) was used to report the pain intensity of their neck and arm, using a scale ranging from 0 (no pain) to 10 (worst pain imaginable). All evaluations were completed preoperatively and at routine postoperative intervals of 1, 3, 6, 12, and 24 months by an experienced resident (L.H.) who was blinded to the patients’ treatment.

**Radiological Evaluation**

Dynamic flexion and extension lateral radiographs were taken in the standing position at all postoperative examinations and compared with those taken preoperatively. Angular range of motion (ROM) for C2-C7 were measured by the difference in Cobb angles between full flexion and extension. A negative value was used to express the lordosis angle, whereas a positive value was used to express kyphosis.

**Statistical Analysis**

Results are expressed as mean ± SD. Repeated-measures analysis of variance was used to compare the differences in NDI, VAS, and angular ROM between the pre- and postoperative examinations for each group. The difference between the 2 groups at each time point was compared by 2-sided Student’s t test. Statistical significance was set at a P value less than .05. All data were calculated using SPSS version 16.0 software (SPSS Inc, Chicago, Illinois).

**RESULTS**

**Patient Populations**

No significant differences in baseline characteristics were found between the 2 groups. All patients were observed clinically and radiologically for more than 24 months. The hybrid constructs group required less operative time and resulted in less blood loss but was not statistically different from the 3-level ACDF group (P > .05) (Table 1).

**Clinical Evaluation**

*Neck Disability Index Scores.* The hybrid constructs group reported significantly improved NDI scores at 1, 3, 6, 12, and 24 months postoperatively relative to preoperative scores (P < .05). The 3-level ACDF group had significantly improved NDI scores at 1, 3, 6, 12, and 24 months postoperatively relative to preoperative scores (P < .05). No significant difference was found in NDI scores between the hybrid constructs group and the 3-level ACDF group during the same follow-up period (Table 2).

*Visual Analog Scale Scores.* The hybrid constructs group reported significantly improved VAS scores at 1, 3, 6, 12, and 24 months postoperatively relative to preop-
erative scores ($P<.05$). The 3-level ACDF group had significantly improved VAS scores at 1, 3, 6, 12, and 24 months postoperatively relative to preoperative scores ($P<.05$). No significant difference was found between the 2 groups during the same follow-up period ($P>.05$) (Table 3).

Radiologic Evaluation. The hybrid constructs group exhibited significantly different C2-C7 ROM at 1, 3, 6, 12, and 24 months postoperatively compared with preoperative ROM ($P<.05$). A significant difference was found between the 2 groups in C2-C7 ROM during the same follow-up period ($P<.05$) (Table 4).

The superior and inferior adjacent segments in the hybrid constructs group had a significantly decreased ROM at 1 month postoperatively ($P<.05$). The ROM at 3, 6, 12, and 24 months postoperatively did not differ significantly from that preoperatively ($P>.05$). The superior and inferior adjacent segments in the 3-level ACDF group displayed a significantly decreased ROM at 1 month postoperatively ($P<.05$). The ROM increased at 3 and 6 months and increased significantly at 12 and 24 months postoperatively when compared with preoperative ROM ($P<.05$). Meanwhile, the ROM in the superior and inferior adjacent segments showed significant differences between the 2 groups at 12 and 24 months postoperatively ($P<.05$) (Tables 5, 6).

Complications

In the hybrid constructs group, 1 patient developed heterotopic ossification without the need for further intervention. No pseudarthrosis or device migration was seen in this group. At final follow-up, no adjacent segment degeneration was found in any patient in the hybrid constructs group. In the 3-level ACDF group, 1 patient developed adjacent segment degeneration and needed another surgical intervention after 27 months. Twenty-four months postoperatively, 1 patient demonstrated asymptomatic implant subsidence, and no specific measure was taken.

Discussion

Anterior and posterior surgeries have advantages for surgical treatment of multilevel cervical disk disease. Posterior sur-
urgery is the primary treatment strategy due to its relative simplicity, low risk, and notable decompression effects. Nevertheless, posterior surgery is associated with limited room to maneuver backward because it does not remove the compression in front and only offers transient decompression, resulting in unfavorable long-term outcomes. Moreover, posterior surgery causes several complications, such as axial pain, kyphotic deformity, and C5 radiculopathy. Anterior cervical decompression and fusion is a standard surgical technique for treating cervical disk disease, with excellent clinical results reported.

However, with the increase in the number of cases and the extension of follow-up, concerns have surfaced with respect to the postoperative outcomes of cervical decompression and fusion, especially multilevel fusion. Some argue that fusion surgery alters the mechanical behavior of the original spine and inevitably modifies the stress distribution and movement patterns of the adjacent vertebral bodies. Biomechanical changes, including concentrated stress, increased compensatory activity, and stability loss, in the adjacent segments creates accelerating degeneration. Single- or multilevel fusion will lead to adjacent segment degeneration, and it is generally thought that multilevel fusion causes increased injury.

Park et al reported that 2-level fusion significantly increased compensatory stress within adjacent intervertebral disks compared with 1-level fusion. They also reported that fusion was more challenging and pseudarthrosis was more likely to occur with increasing instrumented fusion segments. Brodke and Zdeblick found that 1-level ACDF had a fusion rate as high as 97%, whereas the 3-level ACDF fusion rate decreased to 83%. Swank et al determined that the likelihood of pseudarthrosis was 10% in 1-level surgery, 44% in 2-level surgery, and 54% in 3-level surgery.

As such, nonfusion cervical spine surgery has emerged to preserve the motion of the segments operated on and thus reduce the stress on the adjacent segments. Recently, the development of nonfusion cervical spine surgical techniques represented by cervical artificial disk replacement has increased worldwide. Artificial disk replacement maintains the height and ROM of the replaced segments and decreases the stress on adjacent segments, thus reducing or avoiding adjacent segment degeneration.

Previous studies have reported that the use of artificial disk replacement contributes to good clinical and radiological outcomes for 1- and 2-level cervical disk disease. Theoretically, multilevel cervical artificial disk replacement can be performed in patients with multilevel cervical disk disease. Nevertheless, increasing the number of segments to be replaced leads to more technically demanding surgical procedures and more prostheses-related complications. It is sometimes difficult for the surgeons to find an ideal location for the implanted intervertebral disk prosthesis and an exact spatial alignment, which may lead to abnormal ROM of the segment and normal disks postoperatively. How the incremental difference affects the normal physiological function of the cervical spine after multilevel cervical artificial disk replacement remains unknown, but it is an issue of great concern. Therefore, optimal treatment for cervical disk disease involving 3 or more levels needs to be developed.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Pre- and Postoperative VAS Scores</th>
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<tr>
<td>Group</td>
<td>No.</td>
</tr>
<tr>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>Hybrid constructs</td>
<td>12</td>
</tr>
<tr>
<td>3-level ACDF</td>
<td>12</td>
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</table>

Abbreviations: ACDF, anterior cervical diskectomy and fusion; Postop, postoperative; Preop, preoperative; VAS, visual analog scale.

Artificial disk replacement combined with fusion considerably reduces possible complications from multilevel artificial disk replacement and largely maintains segmental ROM, averting the drawbacks of multilevel fusion. In the current study, patients reported significant improvements in postoperative NDI and VAS scores relative to preoperative levels, but no significant differences existed between the 2 groups. Therefore, the current authors believe that the hybrid constructs generate a surgical efficacy similar to traditional fusion procedures for the treatment of cervical disk disease. In addition, both techniques offered favorable decompression effects, restored the ROM at 2 years postoperatively, and preserved neural function, relieved symptoms, and reconstructed cervical stability.

Shin et al reported that compared with 2-level fusion, artificial disk replacement combined with fusion led to faster postoperative recovery of ROM and a largely restored the ROM at 2 years postoperatively, exhibiting a significant difference from the 2-level fusion, which is consistent with the current findings. Therefore, the current authors believe that artificial disk replacement combined with midlevel ACDF for treatment of 3-level cervical disk disease had no significant effect on the overall ROM of the cervical spine. One patient in the hybrid constructs group developed heterotopic ossification, but the occurrence of heterotopic ossification did not affect clinical symptoms and ROM.
In the hybrid constructs group, the superior and inferior adjacent cervical segments showed decreased ROM at 1 month postoperatively compared with preoperative levels. The ROM started to gradually increase at 3 months and became greater than the preoperative levels at 6 months. However, in the hybrid constructs group, the increase in the ROM of the adjacent cervical segments measured at 6, 12, and 24 months postoperatively did not differ significantly from preoperative measurements. The ROM of the superior and inferior adjacent cervical segments in the 3-level ACDF group decreased at 1 month postoperatively. The ROM increased at 3 and 6 months postoperatively and increased significantly at 12 and 24 months postoperatively when compared with preoperative measurements.

At subsequent follow-up, 1 patient required revision surgery for adjacent segment degeneration and 1 patient had implant migration in the 3-level ACDF group. Based on the above data, the authors believe that artificial disk replacement combined with mid-level ACDF may be superior to 3-level ACDF in the prevention of adjacent segment degeneration.

Although current short-term follow-up has shown better clinical outcomes for hybrid constructs, long-term follow-up is necessary to evaluate the safety and effectiveness of this technique, especially with regard to the potential complications and the incidence of adjacent segment degeneration. In vitro biomechanical studies are also needed to further confer the effect of this technique on cervical ROM and adjacent disk levels.

### Table 4

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Mean Preop ROM, deg</th>
<th>Mean Postop ROM, deg</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1 mo</td>
</tr>
<tr>
<td>Hybrid constructs</td>
<td>12</td>
<td>48.6±12.1</td>
<td>28.7±9.3 a</td>
</tr>
<tr>
<td>3-level ACDF</td>
<td>12</td>
<td>47.2±10.3</td>
<td>22.3±6.8 ab</td>
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</tbody>
</table>

Abbreviations: deg, degrees; Postop, postoperative; Preop, preoperative; ROM, range of motion.

*a* Comparison between pre- and postoperative: *P* < .05.

*b* Comparison between hybrid constructs and 3-level anterior cervical diskectomy and fusion: *P* < .05.

### Table 5

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Mean Preop ROM, deg</th>
<th>Mean Postop ROM, deg</th>
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<td></td>
<td></td>
<td></td>
<td>1 mo</td>
</tr>
<tr>
<td>Hybrid constructs</td>
<td>12</td>
<td>14.6±5.2</td>
<td>6.9±4.5 a</td>
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<tr>
<td>3-level ACDF</td>
<td>12</td>
<td>13.8±6.1</td>
<td>9.3±3.6 a</td>
</tr>
</tbody>
</table>

Abbreviations: ACDF, anterior cervical diskectomy and fusion; deg, degrees; Postop, postoperative; Preop, preoperative; ROM, range of motion.

*a* Comparison between pre- and postoperative: *P* < .05.

### Table 6

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Mean Preop ROM, deg</th>
<th>Mean Postop ROM, deg</th>
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<td></td>
<td></td>
<td></td>
<td>1 mo</td>
</tr>
<tr>
<td>Hybrid constructs</td>
<td>12</td>
<td>11.8±3.7</td>
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<tr>
<td>3-level ACDF</td>
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<td>6.9±3.5 a</td>
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</tbody>
</table>

Abbreviations: ACDF, anterior cervical diskectomy and fusion; Postop, postoperative; Preop, preoperative; ROM, range of motion.

*a* Comparison between pre- and postoperative: *P* < .05.
References


