Clinical and radiological results of total disc replacement in the cervical spine with preoperative reducible kyphosis

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Abstract

Purpose To investigate the clinical and radiological results of total disc replacement (TDR) in the cervical spine with preoperative reducible kyphosis, and discuss when TDR is indicated for the patients with preoperative kyphosis.

Methods Fifty-two patients who underwent single-level cervical TDR from June 2008 to May 2010 were included in this study. TDR was indicated for patients with preoperative lordosis or reducible kyphosis, and the patients were divided into a lordotic group (preoperative global angle of $\geq 0^\circ$) and kyphotic group (preoperative global angle of $< 0^\circ$). Clinical results were evaluated using the Japanese Orthopaedic Association (JOA) score, visual analog scale (VAS) score and Neck Disability Index (NDI). For radiological evaluation, the global and functional spinal unit (FSU) angles and the global and FSU range of motion were measured preoperatively and postoperatively.

Results The mean NDI in the kyphotic group was significantly higher than that in the lordotic group preoperatively and at six months postoperatively, but the groups showed no significant differences in JOA score, VAS score and NDI at the two year follow-up. The mean global and FSU angles in the kyphotic group were significantly lower than those in the lordotic group preoperatively and at six months postoperatively, but they gradually improved postoperatively. The differences lost significance at the two year follow-up.

Conclusions Postoperative cervical kyphosis had adverse effects on the NDI after TDR. Artificial discs, symptom relief, and neck functional exercises may contribute to correction of preoperative reducible kyphosis at different stages after cervical TDR. Preoperative reducible kyphosis should not be an independent contraindication for cervical TDR.

Introduction

Anterior cervical discectomy and fusion (ACDF) is a well-established and commonly performed procedure for cervical degenerative disc disorders. However, in the past 20 years, cervical total disc replacement (TDR) has been developed as an alternative non-fusion technique with theoretical advantages. Clinical studies comparing cervical TDR with ACDF have suggested that arthroplasty is comparable to fusion in relief of clinical symptoms at least in the short-term [6, 11, 12, 16]. Furthermore, TDR may reduce the rate of adjacent segment disease by preserving operative level motion and overall cervical kinematics in the long term [3].

With respect to the maintenance and restoration of cervical sagittal balance after anterior decompression as an increasingly important factor for maintaining long-term clinical outcomes, surgeons tend to perform ACDF for patients with preoperative kyphosis, because artificial discs are not initially intended to restore cervical lordosis [4, 8, 9, 13]. Several studies have reported correction of cervical kyphosis after TDR in some cases, but when TDR can be indicated for preoperative kyphosis is unclear [1, 10, 14, 15]. In our clinical experience, preoperative kyphosis can be characterised as reducible or irreducible based on the results of dynamic flexion-extension lateral X-rays. This study was performed to investigate the clinical and radiological results of TDR in the cervical spine with preoperative reducible kyphosis and discuss when TDR is indicated for patients with preoperative kyphosis.

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Patient population

This study included 52 patients who underwent single-level cervical TDR in our department from June 2008 to May 2010. There were 30 men and 22 women with a mean age of 42.5 years (range, 33–58 years).

Inclusion and exclusion criteria for cervical TDR

Inclusion criteria in this study were single-level cervical disc degenerative disorders between C3/4 and C6/7 in patients with radiculopathy and/or myelopathy that had not responded to conservative treatment for three months or the presence of progressive symptoms of nerve root/spinal cord compression. Neurological symptoms were required to be documented with magnetic resonance imaging (MRI). Patients were required to be psychologically, mentally, and physically suitable for TDR.

Exclusion criteria for TDR included significant cervical anatomical deformity, radiographic signs of instability (defined by translation on flexion-extension radiographs of ≥ 2 mm or $\geq 11^\circ$ compared with the adjacent level), and severe spondylosis (defined by bridging osteophytes, disc height loss of $>50\%$, or absence of motion [$<2^\circ$]).

For patients who presented with preoperative kyphosis (preoperative global angle of $<0^\circ$) on a neutral lateral X-ray, TDR was only performed if they could spontaneously improve their sagittal alignment on a flexion-extension lateral X-ray (global angle of $\geq 0^\circ$ on the extension lateral X-ray).

Surgical treatment and device

All operations were performed by the same senior surgeon (D.C.). All patients underwent an anterior cervical discectomy followed by the implantation of an artificial disc prosthesis of suitable size. The Discover Artificial Cervical Disc® (DePuy Spine, Raynham, MA, USA) was the only device used in this study. It is an MRI-compatible ball-and-socket design comprising a superior and inferior end plate and is manufactured from titanium alloy. The inferior end plate is a two-piece design with an ultra-high-molecular-weight polyethylene (UHMWPE-XLK) insert and features a spherical bearing surface between the titanium and UHMWPE-XLK. This bearing surface allows motion in all rotational directions (flexion, extension, lateral bending, and axial rotation), thus accommodating the full range of physiological motion. Each Discover® disc has a built-in 7.0° lordotic angle, which is split evenly between the superior and inferior end plates. This design allows for restoration of lordosis of the treated intervertebral segment. Postoperatively, routine neck activity was initiated after one week of immobilisation in a Philadelphia collar, but the patients were required to perform

strengthening neck functional exercises and increase their neck muscle strength under the doctor's supervision, if postoperative kyphosis remained after most clinical symptoms had been relieved.

Clinical and radiological evaluation

Clinical and radiological outcome measures were collected one, three, six and 12 months postoperatively, and then at regular intervals. Clinical outcomes were assessed using the Japanese Orthopaedic Association (JOA) score, visual analog scale (VAS) score, and Neck Disability Index (NDI). Based on the subjective symptoms, clinical signs, and activities of daily living, the severity of neurological deficits of all patients was scored according to the JOA score. Neck and arm pain relief was evaluated using the VAS score, and neck function associated with activities of daily living was measured with the NDI. Radiological evaluation included neutral and flexion-extension lateral images in a standing position. The global angle of the cervical spine was calculated using Cobb's angle between the inferior margin of C2 and C7 vertebral bodies on a neutral lateral image, and the functional spinal unit (FSU) angle was formed by lines drawn at the superior margin of the superior vertebral body and inferior margin of the inferior vertebral body (Fig. 1). Lordosis was indicated by a positive value and kyphosis by a negative value. The global range of motion (ROM) was measured by the difference in the global angle between the flexion and extension lateral images, and the segmental ROM of FSU was measured by the difference in the FSU angle.

Fig. 1 Radiograph showing the global and functional spinal unit angle measurement techniques on a neutral lateral image

Statistical analysis

The results are presented as means $\pm$ standard deviations. Postoperative results were compared with the preoperative baseline for each group using a paired *t* test. Statistical differences in the clinical and radiological data between the two groups were assessed by the Mann–Whitney *U* test and chi-square test. All statistical analysis was performed using SPSS version 11.0, and the results were considered significant when the *p* value was <0.05 .

Results

Of the 52 patients, 16 (30.8 %) showed preoperative kyphosis on the neutral lateral X-ray, but it could be spontaneously improved on the flexion-extension lateral X-ray (global angle of $\geq 0^\circ$ on the extension lateral X-ray), indicating preoperative reducible kyphosis. The patients were then divided into two groups: the lordotic group (preoperative global angle of $\geq 0^\circ$ on the neutral lateral X-ray) and kyphotic group (preoperative global angle of $<0^\circ$ on the neutral lateral X-ray). There were no significant differences in age, sex, presentation of symptoms, or involved level between the two groups (Table 1).

The clinical results, including JOA score, VAS score and NDI were compared between the two groups. The change trend with the follow-up time is shown in Fig. 2. In both groups, the JOA score, VAS score and NDI all significantly improved within six months after the operation and were well maintained within the two year follow-up. There were no significant differences in the mean JOA and VAS scores between the two groups at any follow-up point. The mean NDI score of the kyphotic group was significantly higher than that of the lordotic group preoperatively and at six months

Table 1 Patient demographics

	Lordotic group (n=36)	Kyphotic group (n=16)
Age (years)	41.7 $\pm$ 6.4	44.2 $\pm$ 9.2
Sex (n [%])		
Male	20 (55.6)	10 (62.5)
Female	16 (44.4)	6 (37.5)
Presentation of symptoms (n [%])		
Myelopathic	19 (52.8)	7 (43.8)
Radicular	6 (16.7)	3 (18.8)
Combined	11 (21.2)	6 (37.5)
Involved level (n [%])		
C3/4	2 (5.6)	1 (6.3)
C4/5	14 (38.9)	6 (37.5)
C5/6	17 (47.2)	8 (50.0)
C6/7	3 (8.3)	1 (6.3)

Fig. 2 Line graphs demonstrating the comparison and change trend of the clinical outcomes of the two groups at each follow-up interval, the *p* values are marked on the top of the figures. **a.** NDI score; **b.** JOA score; **c.** VAS score

postoperatively, but the difference lost significance at the two year follow-up.

The radiological results as evaluated by the global angle, FSU angle, global ROM, and FSU ROM were compared between the two groups, and the change trend with the follow-up time is shown in Fig. 3. There were no significant differences in the mean global ROM or FSU ROM between the two groups at any follow-up point, and the change trend of these two indices was similar. However, different change trends of the mean global and FSU angles were observed in the two groups. In the lordotic group, there were no significant increases in the mean global or FSU angles after the operation. In the kyphotic group, these parameters gradually improved over the two year postoperative follow-up, and there was a significant increase in the mean global angle and

Fig. 3 Line graphs demonstrating the comparison and change trend of the radiological outcomes of the two groups at each follow-up interval; the *p* values are marked on the top of the figures **a**. Change in the

global angle; **b**. Change in the functional spinal unit angle; **c**. Change in the global range of motion; **d**. Change in the functional spinal unit range of motion

FSU angles at six months and two years postoperatively. The mean global and FSU angles in the kyphotic group were significantly lower than those in the lordotic group preoperatively and six months postoperatively, but the difference lost significance at the two year follow-up.

Case presentation

A 34-year-old man had experienced neck and left arm pain, slight numbness in both hands, and walking disturbance for one year. Preoperative MRI demonstrated a typical C4/5 disc herniation with compression of the spinal cord and nerve root (Fig. 4a). A preoperative neutral lateral X-ray showed kyphosis with a global angle of -10.5° and the FSU angle of -12.9° , but kyphosis could be improved on the flexion-extension lateral X-ray. The global ROM was 29.8° and the FSU ROM was 6.5° before the operation (Fig. 4b). Cervical arthroplasty was performed for this patient using a Discover prosthesis.

At six months postoperatively, all of the patient's clinical myelopathy and radiculopathy symptoms were relieved. However, the neutral and flexion-extension lateral X-rays at this time showed no significant improvement in cervical sagittal alignment or ROM: the global angle was -10.3° , the FSU angle was -11.7° ; the global ROM was 32.6° , and the FSU ROM was 6.8° (Fig. 4c). The patient was required to perform strengthening neck functional exercises and increase his neck muscle strength under the doctor's supervision. At the two year follow-up, significant improvement had been achieved in all radiological parameters: the global

angle was 11.8° , the FSU angle was 3.9° , the global ROM was 45.2° , and the FSU ROM was 9.3° (Fig. 4d). This case showed a typical change trend of radiological parameters and the importance of neck functional exercises after cervical arthroplasty for patients with kyphosis.

Discussion

Since the 1990s, cervical TDR with various types of artificial discs has been suggested as a promising alternative nonfusion technique to traditional arthrodesis, preserving spinal mobility in the treated segment and reducing progressive degeneration of the adjacent segments. Cervical disc prostheses may be generally characterised as nonconstrained or semiconstrained according to their kinematics. The Bryan disc, a nonconstrained disc, is reportedly associated with segmental kyphotic angulation, probably because of the endplate milling procedures [5, 7, 10, 15, 17, 18]. On the other hand, the semiconstrained prostheses such as the ProDisc-C may have advantages in restoration of the cervical sagittal alignment but limitations in axial movement and antero-posterior translation [1, 2, 20]. In this study, we used the Discover Artificial Cervical Disc, which is a new cervical prosthesis. The nonconstrained ball-and-socket design accommodated the full range of cervical physiological motion, and a built-in 7.0° lordotic angle was expected to simultaneously allow for restoration of cervical sagittal alignment.

Fig. 4 Radiological images in a patient with preoperative reducible kyphosis showing improvement in cervical sagittal alignment and range of motion during the follow-up period. **a.** Preoperative sagittal and axial magnetic resonance images; **b.** Preoperative neutral and

flexion-extension lateral X-ray; **c.** Neutral and flexion-extension lateral X-ray 6 months postoperatively; **d.** Neutral and flexion-extension lateral X-ray 2 years postoperatively

Correction of cervical kyphosis after cervical prosthesis replacement has been mentioned in several reports [1, 10, 14, 15]. Kim et al. reported that with Bryan disc replacement, a preoperatively kyphotic FSU resulted in a postoperatively lordotic FSU in 13 % of patients and that a preoperatively kyphotic overall cervical alignment resulted in postoperative lordosis in 33 % of patients [10]. However, the indication for TDR for preoperative kyphosis is unclear. In this study, we generally divided preoperative kyphosis into reducible and irreducible based on the results of dynamic flexion-extension lateral X-rays. Reducible kyphosis is usually related to local disc prolapse, patients' clinical symptoms and muscular weakness, but irreducible kyphosis is always associated with significant cervical degeneration or congenital bone malformation. Therefore, TDR was only preformed for patients with preoperative reducible kyphosis.

Our results also showed that preoperative kyphosis was gradually corrected during the follow-up, which may have occurred for several reasons at different stages. Because most clinical symptoms were improved during the first six months after the operation, the time points for postoperative clinical and radiological follow-up evaluations were defined as early (zero to six months) and late (six to 24 months). Increasing of the disc space during the operation and the relief of clinical symptoms in the early stage were responsible for the correction of preoperative kyphosis, but notably, the strengthening neck functional exercises

may have been more important during the late stage. The aim of strengthening neck functional exercises is to increase neck muscle strength, especially the musculature of the back of the neck, which has been proven to be very important in the maintenance of cervical lordosis. In the past, we only emphasised neck muscular exercises in patients who underwent posterior cervical surgery, such as laminoplasty. This was because most anterior operations used instrumentation fixation to correct and maintain cervical lordosis. Based on the results of this study, we may have identified the importance of neck muscle strength in patients undergoing anterior nonfusion TDR. In this study, the clinical and radiological results remained improved after six months in the patients with preoperative kyphosis because they were required to perform strengthening neck functional exercises if they still had postoperative kyphosis after most of their clinical symptoms had been relieved. However, it is preferable that strengthening neck functional exercises begin as early as possible in the patients with preoperative kyphosis.

The influence of preoperative kyphosis on the results of cervical TDR has been reported in a few studies. Yoon et al. reported a significant linear relationship between the preoperative and postoperative global angles [19]. Walraevens et al. reported the same results and suggested that TDR should be cautiously used in patients with preoperative kyphosis [18]. In this study, the clinical and radiological results of TDR in patients with preoperative reducible kyphosis were compared with those in patients with lordosis. A potential

relationship between the NDI and cervical kyphosis was observed because the NDI in the kyphotic group was significantly lower than that in the lordotic group preoperatively and six months postoperatively. However, with the correction of cervical kyphosis in the kyphotic group, there were no significant differences between the two groups in any clinical or radiological results at the two year follow-up. This result shows that preoperative reducible kyphosis should not be an independent contraindication for TDR.

Conflicts of interest The authors declare that they have no conflict of interest.

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