Cervical arthroplasty in the management of spondylotic myelopathy: 18-month results

LALI H. S. SEKHON, M.B.,B.S., PH.D., F.R.A.C.S.

Department of Neurosurgery and Spinal Injuries Unit, Royal North Shore Hospital and The University of Sydney, New South Wales, Australia

Object. Cervical spinal cord compression managed via an anterior approach with an arthrodesis may be associated with a decreased range of motion and accelerated adjacent-segment degeneration. Artificial cervical disc replacement may address these problems.

Methods. The author presents a series of 11 patients (seven men and four women, ages 31–55 years) with anterior cervical decompression and placement of a total of 15 artificial disc prostheses. Clinical and radiological follow-up review was performed at 24 hours, 6 weeks, 3 months, 6 months, and then yearly (mean follow-up period 18.4 months, range 10–32 months). There were no major complications. There was an improvement in the Nurick grade by 0.91 grades ($p < 0.001$) and in the Oswestry Neck Disability Index by 41.5 percentage points ($p < 0.001$). In one case fusion was attained at 17 months postoperatively and one patient had a transient worsening of preoperative symptoms postoperatively, with focal kyphosis. The spinal cord was decompressed on postoperative imaging in all cases.

Conclusions. Cervical arthroplasty after anterior cervical decompression at one or more levels represents an exciting tool in the management of spinal cord compression caused by spondylotic disease or acute disc prolapse. Results obtained in this study add further weight to the potential role of cervical arthroplasty for cervical myelopathy and longer follow up is provided on a previously reported series. It is suggested that care must be taken in using this unconstrained prosthesis if there is a preexisting spinal deformity. Longer follow up will reveal any delayed problems with artificial disc implantation, but in the short to medium term, this technique offers an excellent outcome.

KEY WORDS • arthroplasty • Bryan disc • cervical myelopathy • fusion • stenosis

Cervical arthroplasty has been performed worldwide for more than 3 years. Arthroplasty attempts to redress some of the shortcomings of current anterior arthrodesis techniques. The use of cervical arthroplasty in scenarios in which there is spinal cord compression has been previously reported.[20]

Cervical myelopathy and spinal cord compression caused by spondylotic disease or acute disc herniation is a common spinal disorder that is the subject of controversy over the role and timing of surgical intervention as well as the optimal treatment.[1–3,6,8,12,18,19] Over the past 50 years, various combinations of anterior and posterior instrumented surgeries have been devised and refined and these continue to be used.

In the absence of arthrodesis, kyphotic deformity is always a feared complication.[5,17] The problem with interbody or posterior cervical fusion is that typically a reduction in effective motion occurs and there are significant morbidities associated with bone graft harvest.[13] Coupled with this, the incidence of adjacent-segment deterioration requiring repeated operation has been quoted as being as high as 3% per year.[11] Consequently, there has been an emphasis more recently on surgical techniques such as cervical laminoplasty or cervical disc arthroplasty to maintain motion, avoid deformity, reduce adjacent-segment stresses, and allow for an adequate decompression without having to use bone grafts.

This study expands a previous one in which the use of artificial disc implantation in the management of spinal cord compression and cervical myelopathy was described. Longer follow-up findings in the original seven patients are given, with additional cases described. Although the use of the Bryan Cervical Disc (Medtronic Sofamor Danek, Memphis, TN) in cervical spine disease has been reported before,[9,10,21] in this series I specifically evaluate the use of cervical arthroplasty in spinal cord compression caused by spondylotic disease or acute disc herniation.

CLINICAL MATERIAL AND METHODS

Patient Population

The 11 patients presented in this study were recruited over a 31-month period, with all operations performed by a single surgeon. Seven of these patients were previously presented in a report with a shorter follow-up duration.[20] All patients had undergone preoperative MR imaging of the cervical spine that had demonstrated spinal cord compression and/or had a clinically confirmed cervical myelopathy. All would normally have qualified for and would be offered an anterior cervical decompression and fusion with iliac crest autograft and instrumentation.

Abbreviations used in this paper: CT = computerized tomography; MR = magnetic resonance; NDI = Neck Disability Index.

Exclusion criteria for this group included kyphotic deformity, severe multilevel spondylotic disc degeneration, spinal cord injury with possible instability, and pure radiculopathy secondary to posterolateral disc protrusion or foraminal stenosis. If the affected disc space could not be visualized on a lateral cervical x-ray film obtained with the patient supine, cervical arthroplasty was not offered. The group was nonrandomized but was prospectively followed. All patients requested cervical arthroplasty after the various surgical options were discussed.

The demographics of the patients selected for this study are summarized in Table 1. There were seven men and four women whose ages ranged from 31 to 55 years (mean age 43.7 years), and symptoms had lasted between 0.75 and 72 months (mean 15.2 months). Two (18%) of the 11 patients were active cigarette smokers. All patients underwent a detailed neurological examination and Nurick grading[15] preoperatively. All patients completed an Oswestry NDI assessment[23] and also scored their neck and arm symptoms on a scale from 0 to 3 (0, none; 1, mild; 2, moderate; and 3, severe). In all patients preoperative static and dynamic x-ray films were obtained as well as MR images and CT scans of the cervical spine. All imaging studies were independently reviewed. It was explained that if the surgeon discovered intraoperatively that arthroplasty could not be done, an interbody fusion would be performed.

Preoperative assessment revealed that six (55%) of 11 patients had myelopathic dysfunction of at least Nurick Grade II. Eight (73%) of 11 patients had symptoms or signs of radiculopathy in addition to myelopathic symptoms or signs. No patient had pure radiculopathy, and none had absence of spinal cord compression on imaging. Six (55%) of 11 patients had high signals in the spinal cord, which indicated edema or myelomalacia on T_2-weighted MR imaging. A typical preoperative MR image is shown in Fig. 1.

Osteophytic compression was present in 10 (86%) of 11 cases, with significant disc herniation in four (37%) of 11 cases. No patient had severe preoperative kyphotic deformity, but five (45%) of 11 did have loss of normal cervical lordosis, with one patient displaying a mild upper cervical kyphosis. Dynamic cervical x-ray films obtained preoperatively showed no evidence of instability or hypermobility.

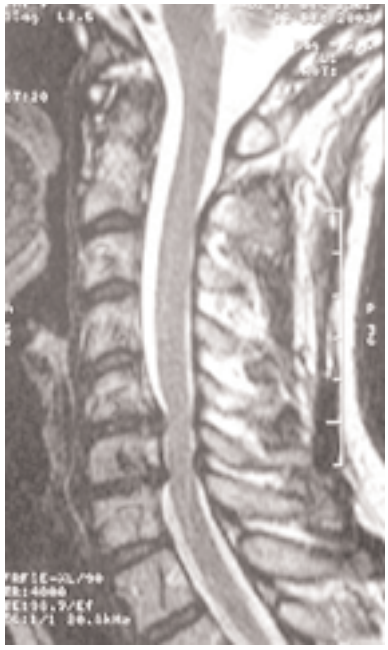

Fig. 1. Case 11. Preoperative sagittal T_2-weighted MR image revealing spinal cord compression secondary to spondylotic disease at both the C5–6 and C6–7 levels.

Surgical Procedure

Surgical intervention followed the recommendations of the designers of the Bryan disc (Medtronic Sofamor Danek). The surgical technique has been described elsewhere.[9,20,21] Briefly, after the induction of general anesthesia, endotracheal intubation was effected and the procedure was performed under fluoroscopic control with the patient supine. The patient's head was placed in gentle extension on a soft cushion with a rolled towel behind the

TABLE 1

*Demographic data in 11 patients treated with cervical arthroplasty**

Case No.	Age (yrs), Sex	Preop Nurick Grade	Preop Neck Sxs†	Preop Arm Sxs†	Preop Oswestry NDI	Smoking History	Acute Disc Herniation	Duration of Sxs (mos)	SC Signal Δ on MRI	Preop Cervical Deformity
1	38, M	II	1	0	42	no	no	3.0	yes	loss of lordosis
2	55, F	I	2	3	76	no	no	6.0	no	loss of lordosis
3	46, M	I	1	3	66	yes	yes	0.75	no	loss of lordosis
4	47, M	III	1	1	34	no	no	4.0	yes	loss of lordosis
5	49, F	I	2	3	58	no	no	9.0	yes	loss of lordosis
6	31, M	I	3	1	80	no	no	72.0	no	lordosis
7	34, F	III	2	3	42	yes	yes	18.0	yes	kyphosis
8	36, M	III	1	0	38	no	no	3.0	yes	lordosis
9	37, M	III	1	0	42	no	no	4.0	no	lordosis
10	54, F	I	3	3	74	no	no	34.0	yes	lordosis
11	54, M	III	2	1	44	no	no	14.0	no	lordosis

* All patients had cervical spondylosis, and all had spinal cord compression on preoperative MR images. Abbreviations: SC = spinal cord; sx = symptom; Δ = change.

† 0, no symptoms; 1, mild symptoms; 2, moderate symptoms; 3, severe symptoms.

neck. For single-level disease a left-sided transverse cervical skin incision was used, and for two-level disease either this incision or an oblique left-sided paramedian one was used.

On two occasions the C6–7 disc space was difficult to view radiographically with the patient supine, although it had been visible with them upright, and in these cases careful arm retraction as well as digital fluoroscopy directed down to the affected level was required. No operation was abandoned because of this problem. An extensile exposure of the anterior cervical spine was accomplished, and after standard microsurgical decompression of the spinal cord one or more artificial disc prostheses were placed. The posterior longitudinal ligament was excised in every case. The sizes of the prostheses ranged in diameter from 14 to 18 mm. No cervical collar was placed postoperatively. All patients were monitored in our high-dependency unit overnight and mobilized the day after surgery. All patients were discharged within 48 to 72 hours postsurgery, and all had returned to work within 2 to 4 weeks.

Postoperative evaluations incorporated the same intervals for clinical and radiological evaluations that were used preoperatively. Postoperative evaluations were performed at 24 hours, 6 weeks, 3 months, 6 months, and then yearly (Figs. 2–5). An independent radiologist assessed all images. Static and dynamic x-ray films were obtained at every follow-up visit, but MR imaging was only done at 6 weeks and then yearly thereafter. The CT scans were obtained at 24 hours, at 6 and 12 months, and then yearly thereafter. Follow-up periods ranged from 10 to 32 months (mean 18.4 months). An assessment of overall surgical outcome was made using Odom criteria[16] (Table 2), in addition to the other outcome measures discussed previously. The intra- and postoperative outcomes are summarized in Table 3. The pre- and postoperative Nurick grades, Oswestry NDI scores, and arm and neck symptom scores were compared using two sample t-tests paired for means. A probability value less than 0.05 was regarded as significant. All scores were expressed as the mean ± standard error of the mean.

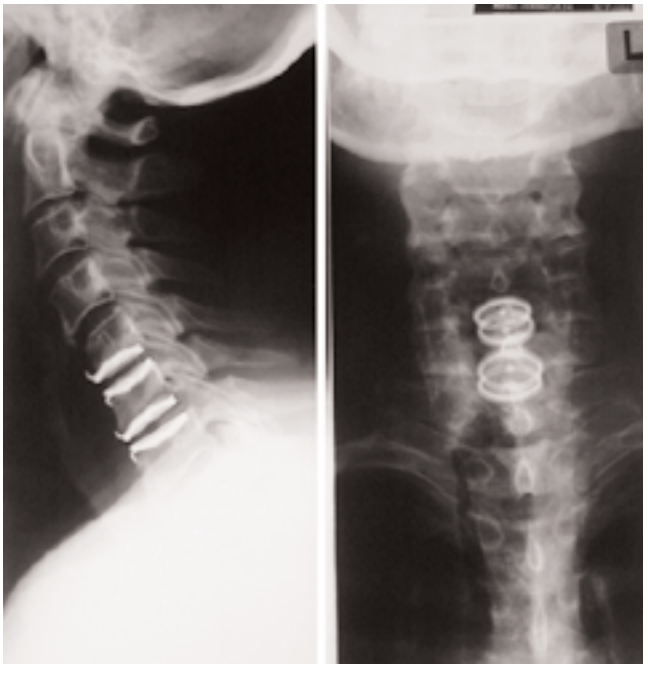

Fig. 2. Case 11. Postoperative anteroposterior (A) and lateral (B) x-ray films obtained after placement of an artificial disc prosthesis at the C5–6 and C6–7 level. The prosthesis is centered on the disc space.

RESULTS

A total of 15 prostheses were inserted in 11 patients. In this group, 73% of prostheses were placed at either C5–6 or C6–7. There were no complications in the intra- or postoperative period and all patients noted immediate improvement in preoperative symptomatology (Table 3). Looking first at clinical outcome, it is apparent that there was a significant improvement in subjective neck and arm symptoms. Neck symptom scores improved from 1.73 ± 0.79 to 0.55 ± 0.82. Arm symptom scores improved from 1.64 ± 1.36 to 0.18 ± 0.6. The Oswestry NDI scores improved from 54.2 ± 17 to 12.7 ± 12.1. Both smokers had excellent outcomes. On clinical assessment there was a statistically significant improvement in the Nurick grade from 2 ± 1 to 1.09 ± 0.3 ($p < 0.001$ for all four preceding comparisons).

Results of radiological imaging performed postoperatively are represented in Figs. 2 through 5 and in Table 3. A typical series of postoperative static and dynamic x-ray films are shown in Figs. 5A and B. When looking at the overall balance of the spine after arthroplasty, of significance was the fact that three patients experienced worsening of their preoperative alignment in terms of either loss of preoperative lordosis or slight kyphosis. All patients demonstrated a good range of cervical motion on fluoroscopic screening at the final postoperative assessment.

When surgical outcome was measured using Odom criteria, it was concluded that 91% of patients had a good or excellent outcome (see Table 3). Two patients did have adverse outcomes. The first (Case 7) involved a 34-year-old woman who presented with a rapidly progressive myeloradiculopathy and who underwent two-level decompression and arthroplasty. The procedure was uncomplicated, and she appeared to be well after surgery. Approximately 10 days postsurgery she was readmitted with worsening of her preoperative hand and gait dysfunction. A CT myelogram revealed no persistent compression, and in the course of 72 hours her symptoms resolved with dexamethasone therapy. Of interest was the kyphotic angulation of her upper arthroplasty shells, with worsening of a preoperative kyphosis by 6°. Her overall balance was unchanged, however, but the focal motion segment had become more kyphotic. On MR images obtained 12 months postsurgery there was no evidence of persistent spinal cord compression but myelomalacia was present (Fig. 6).

The second patient was a 55-year-old woman who presented with a C-6 radiculopathy and who underwent a C5–6 arthroplasty for significant spinal cord compression. Again, the procedure was uncomplicated. Her neck pain persisted along with arm pain after surgery, despite antiinflammatory medication. Significantly, there was loss of motion at the instrumented level on postoperative dynam-

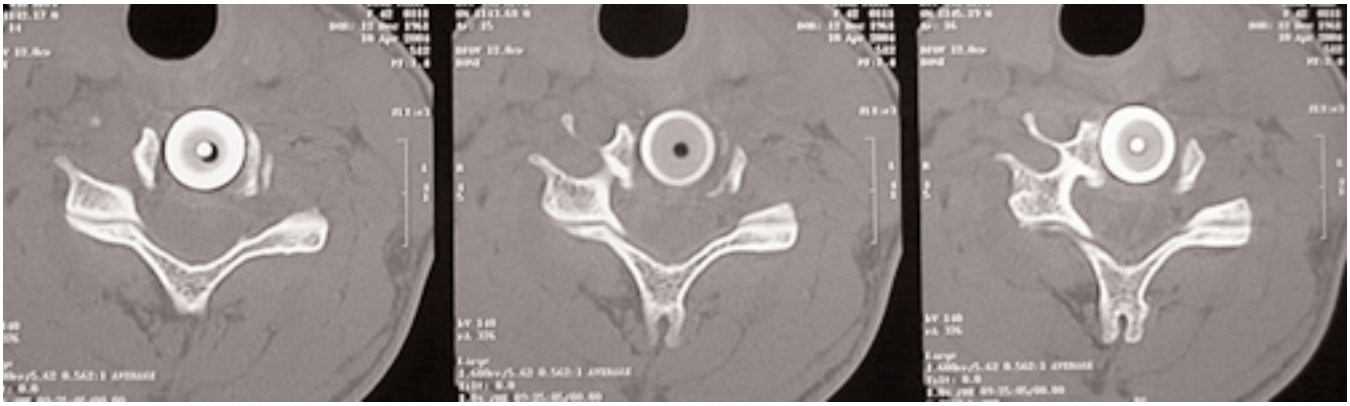

Fig. 3. Case 11. Postoperative axial CT scans demonstrating the artificial disc prosthesis in place after surgery. The prosthesis occupies most of the space previously taken by the intervertebral disc.

ic imaging. Seventeen months after surgery, it was evident that spondylotic bridging had occurred behind the prosthesis, creating an interbody fusion (Fig. 7). The patient still had some degree of neck and arm pain but refused further surgery and the prosthesis was not removed. This case is described elsewhere (unpublished data).

There were no deaths in the treated group, and no patients were lost to follow up. The postoperative outcome scores listed in Table 3 are the most recent ones.

DISCUSSION

The Bryan Cervical Disc Prosthesis was first reported as being used for the management of cervical spondylotic disease in 2002 by Goffin, et al.,[9] and subsequently by Sekhon.[21] This prosthesis consists of a polyurethane nucleus designed to fit between two titanium alloy shells. Each shell has an outer porous coating made of titanium to encourage bone ingrowth and long-term stability. A polyurethane sheath surrounds the nucleus and is attached to the shells with titanium wire, forming a closed compartment. Sterile saline is placed into the prosthesis and titanium alloy seal plugs provide for its retention. This prosthesis requires precise milling for its placement, and the technique aims at meticulous centering of the device. Multiple levels can be instrumented, but they must be viewed on fluoroscopy.

Goffin, et al.,[9] described the use of cervical arthroplasty in an attempt to maintain cervical motion and avoid arthrodesis after decompression. In their study, 60 patients underwent single-level anterior cervical decompression and placement of an artificial disc prosthesis. Of note is that 93% of their patients had predominantly radiculopa-

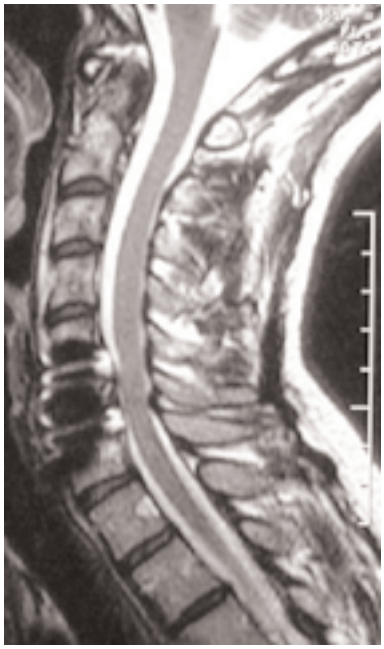

Fig. 4. Case 11. Postoperative sagittal T_2-weighted MR image obtained after C5–6 and C6–7 arthroplasty. The MR image reveals that the titanium shells do create an artifact with this modality but the canal can still be seen. This was not the case with every postoperative MR image.

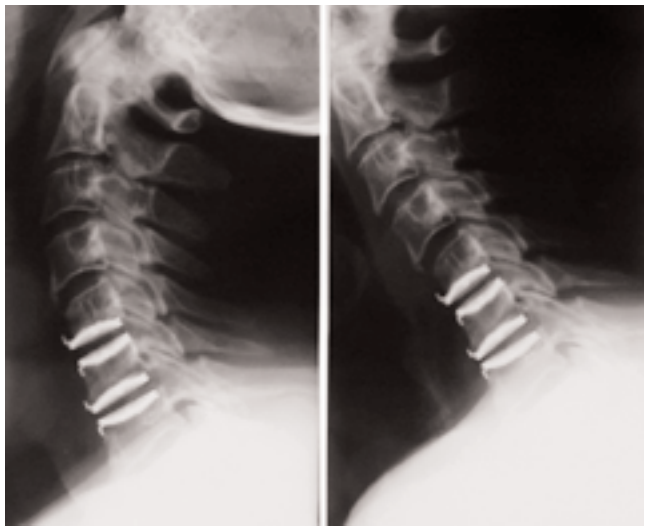

Fig. 5. Case 11. Lateral flexion *(left)* and extension *(right)* x-ray films obtained 6 weeks postsurgery. Note that normal movement occurs at the instrumented level, as demonstrated by the crowding then splaying of the spinous processes.

TABLE 2

Definitions of grades according to the Odom criteria

Grade	Definition
excellent	all preop sxs relieved, able to perform daily occupations w/o impairment
good	min persistence of preop sxs, able to perform daily occupations w/o significant interference
fair	relief of some preop sxs, but physical activities significantly limited
poor	sxs & signs unchanged or worse

thy. These authors reported follow-up findings at 12 months, with clinical success stated at between 85 and 90%. No subsidence of the devices was noted and two patients possibly had device migration. No spondylotic bridging occurred at the implanted disc space. The range of motion was preserved and no device had been explanted or surgically revised. They have subsequently reported on 3-year results in this group and a similar 1-year follow-up report on bilevel replacements has shown equally acceptable results.[10]

In this study I present further information in the short to medium term on the outcome of cervical arthroplasty in patients with cervical stenosis/myelopathy. Patient follow-up findings have been reported up to 31 months, with half the group having been followed for more than 18 months. Significant complications included fusion across the prosthesis at 17 months, one myelopathic deterioration possibly attributable to swelling or edema, and three cases in which the preoperative alignment appeared to have worsened. As a group, however, almost all patients had made a good or excellent recovery with serial CT and MR imaging studies revealing no new abnormalities. Significantly, there was no evidence of recurrent stenosis. Clearly, longer follow-up duration will be required.

The issue of fusion of the prosthesis has been discussed elsewhere (unpublished data). This patient was among the first seven patients in whom results were reported and did not attain fusion until 17 months postsurgery. This illustrates the importance of prolonged follow-up periods for these individuals. McAfee, et al.,[14] reported that heterotopic ossification occurs in 2 to 53% of hip arthroplasties. They commented that heterotopic ossification after hip arthroplasty occurs most readily in the hypertrophic type of osteoarthritis and that the true incidence after lumbar arthroplasty is unknown. Using their four-tiered classification system, Case 2 would be categorized as Class 4, with complete ankylosis and bridging bone. Recently, Tortolani, et al.,[22] have looked at heterotopic ossification after cervical arthroplasty. They noted that in most cases ossification occurred in the first 100 days. Typically it occurred lateral to the vertebral bodies and could potentially be reduced through the judicious use of antiinflammatory medications postoperatively.

Spontaneous fusion after arthroplasty has been demonstrated in the lumbar spine. In a series of 96 patients undergoing implantation of the Link SB Charité III lumbar disc prosthesis (Waldemar Link, Hamburg, Germany), David[7] reported on five patients who attained complete ossification around the implant. Interestingly, in our case, ossification did not occur laterally, and it occurred despite antiinflammatory medication.

The patient in Case 7 had high-grade stenosis with mild kyphotic deformity prior to surgery. After two-level arthroplasty, focal kyphosis was evident at the upper level, with a delayed, unexplained deterioration that resolved and may have been attributable to the worsening of local motion segment angulation as a result of the arthroplasty. In this case, it is possible that use of an unconstrained prosthesis led to worsening of preoperative deformity and the outcome in this case cautions against the use of such a prosthesis in patients with preoperative kyphosis, because worsening of deformity may occur on remobilization. Newer semiconstrained prostheses may eliminate this shortcoming.

No patient required prosthesis removal, with 3 years being the longest a device has been in place to date. In the expected life span of these prostheses[4] this is still a relatively short time, and it may take more than 10 years of follow up before in vivo wear can be more fully evaluated.

TABLE 3

*Results in 11 patients treated with cervical arthroplasty**

Case No.	Levels Replaced	Size of Prosthesis (mm)	FU (mos)	Postop Nurick Grade†	Postop Neck Sxs†	Postop Arm Sxs†	Postop Deformity	Postop Oswestry NDI†	Outcome According to Odom Criteria
1	C5–6	15	31.9	I	0	0	loss of lordosis	2	excellent
2	C5–6	14	29.3	I	2	2	loss of lordosis	8	good
3	C6–7	15	24.6	I	0	0	loss of lordosis	16	excellent
4	C6–7	17	18.0	I	0	0	loss of lordosis	0	excellent
5	C5–6, C6–7	16 x 2	17.2	I	0	0	lordotic	2	excellent
6	C6–7	15	13.7	II	1	0	lordotic	10	good
7	C4–5, C5–6	15 & 16	15.9	I	0	1	kyphosis	0	fair
8	C3–4	16	11.8	I	0	0	lordotic	18	excellent
9	C4–5	16	11.7	I	1	0	loss of lordosis	22	excellent
10	C4–5, C5–6	17 & 16	10.4	I	2	0	kyphosis	38	excellent
11	C5–6, C6–7	16 & 18	18.0	I	0	0	lordotic	24	excellent

* FU = follow up.

† Statistically significant difference compared with preoperative values ($p < 0.01$).

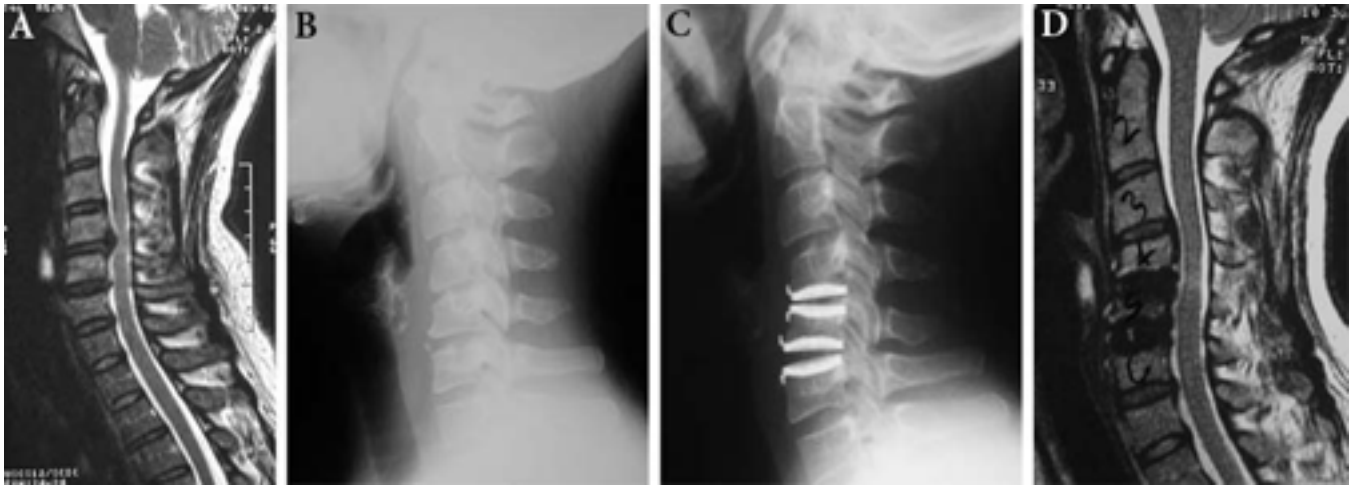

Fig. 6. Case 7. Preoperative T_2-weighted sagittal MR image (A), preoperative lateral cervical spine x-ray film (B), postoperative T_2-weighted sagittal MR image (C), and postoperative lateral cervical spine x-ray film (D) obtained in this patient. It is notable that severe stenosis was present preoperatively, with mild kyphosis of the upper cervical spine. After surgery kyphotic angulation of the upper prosthesis shells occurred, but the spinal cord was not compressed on MR imaging performed 12 months postsurgery.

CONCLUSIONS

Artificial cervical disc placement is a satisfactory management option for the treatment of cervical myelopathy after anterior cervical decompression, with good medium-term results. Low morbidity combined with an excellent postoperative outcome and avoidance of the known problems associated with cervical arthrodesis or allograft/autograft usage indicates that this procedure will play an important role in the management of spondylotic cervical myelopathy. Multicenter studies are underway and longer follow-up periods are required. Recurrent stenosis is the feared complication that may potentially occur because arthrodesis has not been achieved, as is potential wear of the prosthesis over time. Balance needs to be looked at more rigorously. Nevertheless, this technology presents the spine surgeon with another exciting tool that he/she can use in the management of cervical myelopathy.

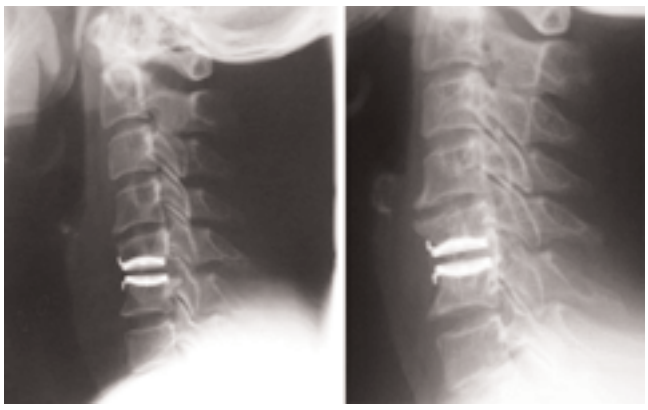

Fig. 7. Case 2. Lateral cervical spine x-ray films obtained 6 weeks postsurgery *(left)* and 17 months postsurgery *(right)*. Fusion of the interspace is noted, with bone bridging across the posterior margin of the prosthesis.

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Address reprint requests to: Lali Sekhon, Level 10, Tower B 799 Pacific Highway, Chatswood, New South Wales, 2067 Australia. email: lali@spinalneurosurgery.com.