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Cervical Disc Arthroplasty: General Introduction

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Anterior cervical discectomy and fusion (ACDF) of one or two levels for spondylotic myelopathy or radiculopathy has proven to be an extremely effective procedure in terms of clinical and radiographic outcomes [1–4]. Nevertheless, the risk of inducing accelerated degeneration or a disease of adjacent segments and the difficulty of treating adjacent segment disease after fusion remain significant drawbacks to fusing a cervical spinal motion segment. The rate of adjacent segment degeneration has been reported to be as high as 3% to 11% per year for the first decade after fusion, with up to two thirds of patients requiring reoperation [5,6]. Hypermobility of segments adjacent to a fused segment is also often observed [7]. Moreover, the need for supplemental anterior plate fixation after ACDF can increase the risk of postoperative dysphasia and instrumentation failure. Therefore, although one- or two-level ACDF remains an effective treatment for degenerative disc disease of the cervical spine, these drawbacks have sparked efforts to design alternative and innovative surgical strategies to treat cervical disc disease. Cervical disc arthroplasty is one such innovation that potentially eliminates the disadvantages associated with ACDF, while maintaining similar or improved clinical outcomes. Here, we review the potential advantages of cervical disc arthroplasty for the treatment of cervical degenerative disc disease and the reported clinical outcomes and summarize important directions for future research in cervical disc replacement technology.

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Rationale for cervical disc replacement

Cervical disc replacement for the treatment of cervical disc disease offers three distinct advantages compared with ACDF (Table 1).

Decreased rate of progression of adjacent segment degeneration

Cervical disc replacement may alter the natural rate of progression of adjacent segment degeneration. Degeneration of a cervical spinal motion segment alters the biomechanical and physiologic environment of the affected and adjacent spinal segments, causing alterations in the axis of rotation, load sharing, and a decline in the nutritional supply [8]. Thus, the degenerative process affecting a particular cervical motion segment may lead to accelerated degeneration at adjacent segments. By restoring normal disc height and motion to a diseased cervical spinal motion segment, cervical disc replacement may reduce adjacent segment stresses and slow or even reverse the natural progression of adjacent segment degeneration in the nonfused but diseased cervical spine (Fig. 1). Moreover, the risk of accelerated adjacent segment degeneration and hypermobility after fusion is eliminated.

Improved treatment of adjacent segment disease

Surgical treatment of adjacent segment disease after ACDF is difficult and is associated with an increased risk of dysphagia and pseudoarthrosis [9]. This is attributable to the fact that the biomechanical stresses on the disc space adjacent to a solid fusion are altered as a result of the differential in stiffness between the fused and nonfused segments. This environment makes successful arthrodesis of the degenerated adjacent

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Table 1
Advantages of cervical disc arthroplasty over anterior cervical discectomy and fusion

Measurement	ACDF	Cervical disc arthroplasty
Spinal segmental motion	Absent	Normal
Incidence of adjacent segment disease	Increased	Decreased
Intraoperative morbidity		
Supplemental instrumentation	Anterior cervical plate	None
Autograft harvest	Iliac crest (smokers)	None
Exposure	Equal	Equal
Operative time	Equal	Equal (after learning curve)
Postoperative morbidity		
External immobilization	Rigid cervical collar	None
Return to normal activity	At least 1 month	As early as 1 to 2 weeks
Pseudoarthrosis rate	Increased	Absent
Instrumentation failure	Minimal	Minimal

Abbreviation: ACDF, anterior cervical discectomy and fusion.

segment even more problematic. Moreover, because the success rate of ACDF significantly decreases as the number of levels fused increases, the morbidity of fusion procedures to treat adjacent segment degeneration is substantial [9]. Because the success of cervical disc replacement does not depend on establishing solid arthrodesis but rather on restoring normal motion, this technique may be a more effective treatment for adjacent segment disease in which an unfavorable biomechanical environment for fusion already exists. Indeed, Pimenta and colleagues [10] have reported good results in 10 patients with degenerative adjacent segment disease of the cervical spine attributable to postsurgical or congenital arthrodesis treated with the Porous Coated Motion (PCM; Cervitech, Rockaway, New Jersey) disc prosthesis.

Reduction of intraoperative and postoperative morbidity and earlier return to activity

The most practical and immediately appreciable benefit of cervical disc replacement may be in the reduction of operating time and postoperative morbidity. First, cervical disc arthroplasty requires no interbody bone graft, thus eliminating the need for iliac crest autograft harvest, which results in reduced operative time and postoperative morbidity. During an ACDF procedure, an anterior cervical plate is often placed to support the interbody graft. This not only adds additional time to the procedure but, in cases of multilevel or adjacent level procedures, requires more dissection, with the risk of postoperative swallowing dysfunction. Moreover, there is a small but appreciable risk of postoperative plate failure or backout. This is particularly true with cervical junctional or buttress plates [11]. Cervical disc replacement, conversely, requires no additional anterior plate fixation, thus reducing intraoperative time and surgical dissection and eliminating the risk of postoperative screw and/or plate backout. In addition, multilevel ACDF procedures often require supplemental posterior lateral mass screw-rod fixation for successful arthrodesis. No additional posterior instrumentation is required after disc arthroplasty. Most patients are subjected to immobilization in an external orthosis after ACDF. Cervical disc replacement eliminates the need for postoperative rigid external immobilization, and patients are able to return to normal activities as early as 1 to 2 weeks after surgery [12]. Zigler [13] reported that patients treated with the ProDisc II lumbar disc prosthesis (Synthes Spine Solutions, West Chester, Pennsylvania) had significantly increased activity at 3 months compared with patients treated with fusion. Finally, unlike after ACDF, there is no loss of cervical range of motion after disc replacement.

Design classifications

The material properties of three of the most commonly used cervical disc prostheses are given in Table 2.

Indications for cervical disc arthroplasty

Cervical disc replacement is currently indicated for patients with myelopathy or radiculopathy caused by degenerative cervical disc disease at one or two levels. Alternative indications include arthroplasty of three or more levels or of a degenerated segment adjacent to a fusion [14]. Its use in the management of axial neck pain is as yet

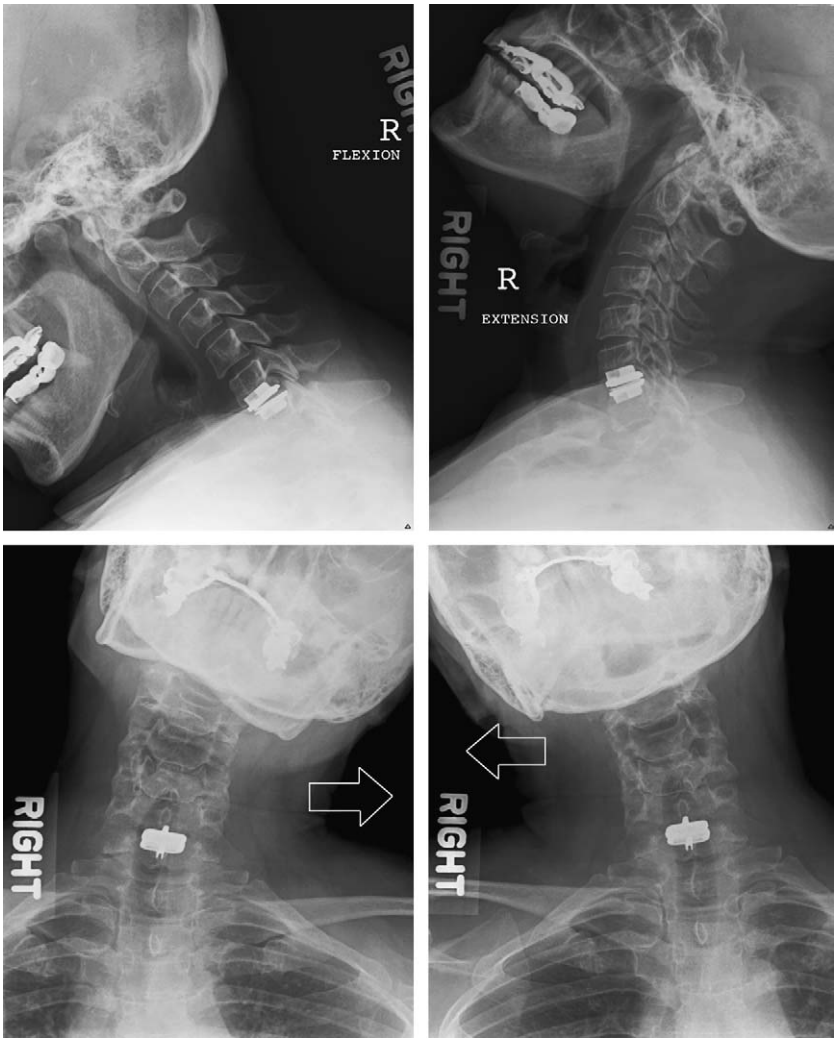

Fig. 1. Lateral flexion (*top left*), extension (*top right*), anterior-posterior right lateral bending (*bottom left*), and anterior-posterior right lateral bending (*bottom right*) plain radiographs of the cervical spine in a 55-year-old woman with radiculopathy from central disc herniation treated with C6 to C7 discectomy and cervical disc arthroplasty with the ProDisc C artificial disc. Note that motion is preserved in all axes tested.

unknown. Contraindications include instability, facet arthropathy, and infection.

Clinical outcomes

Although long-term and class I data are lacking, initial 1- and 2-year data indicate that cervical disc replacement compares favorably with equivalent data for patients treated with ACDF [8,10,15–20] and that patients experience less postoperative pain and discomfort [21]. Bertagnoli and coworkers [22] reported a significant improvement in pain and functional outcome scores in 16 patients with symptomatic cervical spondylosis (12 one-level and 4 two-level procedures) treated with the ProDisc-C cervical disc prosthesis (Synthes Spine Solutions) at 12 months of follow-up. At 18 months of follow-up, Sekhon [23] found an improvement of 0.91 points in Nurick grade and 41.5 percentage points in the Oswestry Neck Disability Index in 11 patients after cervical arthroplasty with the Bryan Cervical Disc (Medtronic Sofamor Danek, Memphis, Tennessee). In a prospective multicenter study of the Bryan Cervical Disc, Goffin and colleagues [12] reported clinical success in 85% of cases of

Table 2
Properties of cervical disc prostheses

Disc prosthesis	Material	Articulating surface	Motion	Fixation
ProDisc C	CoCrMo	Metal-polymer	Semiconstrained	Keel
Bryan	Titanium alloy, polyurethane	Metal-polymer	Unconstrained	Bone ingrowth/milling
Prestige	Stainless steel	Metal-metal	Semiconstrained	Screw fixation

Abbreviation: CoCrMo, cobalt chromium molybdenum.

one- and two-level disc replacement at 12 months of follow-up. In one of the longest follow-up intervals to date, Robertson and Metcalf [24] reported sustained clinical improvement with continued preservation of motion after cervical disc replacement with the Prestige I disc (Medtronic Sofamor Danek) at 3 and 4 years of follow-up.

Complications

Although the advantages of cervical disc arthroplasty are significant, the goal of motion preservation at a diseased cervical spinal segment must be tailored to a patient's particular pathologic findings. Young patients with soft disc herniations or mild spondylotic changes, for example, may benefit substantially from cervical disc replacement and segmental motion preservation versus segmental fusion. Conversely, patients with severe cervical spondylosis may be susceptible to recurrent osteophyte formation with retention of motion at a diseased cervical spinal segment. Indeed, there have been reports of recurrent radiculopathy and heterotopic ossification in patients treated with disc replacement for cervical spondylosis [25]. Thus, wider uncinate resection and osteophyte removal may be necessary before disc replacement in patients with severe cervical spondylosis [26]. It is important to note, therefore, that symptomatic relief after ACDF or cervical disc arthroplasty is dependent on adequate decompression. This is especially important after disc replacement, because the advantageous effects of fusion on bone remodeling and disc osteophyte resorption are absent.

No cases of subsidence of cervical disc prostheses have been reported in the literature to date. Goffin and coworkers [12] reported one case of minimal anterior displacement of a Bryan Cervical Disc prosthesis because of incomplete end plate milling without the need for additional surgery.

Summary

For patients with degenerative disease of the cervical spine causing myelopathy or radiculopathy, cervical disc arthroplasty has the potential to provide the clinical benefits associated with ACDF procedures while avoiding the morbidity of fusing a cervical spinal motion segment. Normal range of motion, joint biomechanics, alignment, and foraminal height are preserved; the risk of adjacent segment disease and intraoperative morbidity is decreased; and functional outcome is improved. Early clinical results indicate outcomes similar to discectomy and fusion procedures, with slightly lower rates of complications. Although there are currently a handful of different disc replacement designs and materials in use, no study has addressed the effect of these differences on patient outcome. Although results have been promising to date, further randomized studies and long-term outcome data are necessary before conclusions can ultimately be made about the clinical efficacy and exact indications for cervical disc replacement.

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