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Contemporary Concepts Review

# Lumbar disc arthroplasty

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**Abstract**

**BACKGROUND CONTEXT:** Painful lumbar disc degeneration is one of the most common ailments treated by spine surgeons. Currently, early disc disease and herniation are often treated with microdiscectomy. Late disc degeneration is usually treated with arthrodesis. With the advent of new technology and techniques in lumbar disc arthroplasty, interest in preserving spinal motion at degenerated motion segments has increased. The goals of lumbar disc arthroplasty are to provide long-term pain relief at the degenerated disc level, to restore disc height to protect neural elements and to preserve motion to prevent posterior facet arthropathy and adjacent segment disease.

**PURPOSE:** The purpose of this review is to examine the anatomy and biomechanics of the lumbar motion segment to determine the features that successful disc arthroplasty prosthesis must possess. In addition, the early clinical results of three prostheses currently being used in humans are reviewed.

**STUDY DESIGN/SETTING:** Review of the literature.

**METHODS:** A systematic review of Medline for articles related to lumbar disc arthroplasty was conducted up to and including journal articles published in August 2003. In addition, the abstracts from the annual meetings of the North American Spine Society and Scoliosis Research Society from 1998 to 2003 were searched. The literature was then reviewed and summarized.

**RESULTS/CONCLUSIONS:** Short-term results of lumbar disc arthroplasty as measured by pain relief and disability are good in some studies. Implants are relatively safe in the short term, and with newer designs complications are usually related to the surgical approach rather than early implant failure. Recovery times appear to be shorter than arthrodesis. Despite the relatively good early clinical results of these devices, questions remain about the long-term efficacy in pain relief and maintenance of motion, the results of randomized comparative trials with fusion and the life span of the devices. In addition, late sequelae and revision options are unknown. Current indications for lumbar disc arthroplasty are in the setting of a Food and Drug Administration trial in young, nonosteoporotic patients with one or two level symptomatic disc degeneration without severe facet arthropathy, segmental instability or neural element compression requiring a posterior decompression.


*Keywords:* Disc arthroplasty; Lumbar spine; Disc degeneration; Spine prosthesis; Artificial disc; Intervertebral disc

## Introduction

Lumbar disc degeneration is one of the most commonly encountered disorders in spine surgery practices. If conservative measures fail, surgical treatment of symptomatic disc degeneration is guided by the severity of the disc pathology and the stability of the motion segment. Currently, lumbar disc herniation is commonly treated with microsurgical discectomy. For severe disc degeneration, spinal arthrodesis is usually performed. Motion at the diseased segment is generally thought to provoke pain at the diseased level; therefore, arthrodesis has become a popular option in the United States for severe degenerative lumbar disc disease. Despite a clinical success rate of between 60% and 90% for arthrodesis [1–4], it remains a less than ideal solution for some disc pathology. Complications such as bone graft donor site pain, persistent low back pain and pseudarthrosis are still prevalent despite newer, more rigid instrumentation systems [5–8]. In addition, some investigators feel that fusion of one

FDA device/drug status: investigational/not approved (SB Charité III disc [Waldemar Link, Hamburg, Germany]; Prodisc II prosthesis [Spine Solutions, New York]; prosthetic disc nucleus [RayMedica Inc., Bloomington, MN]).

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spinal motion segment predisposes the adjacent segments to accelerated disc and facet joint degeneration [9–11].

The traditional dogma that rigid spinal fusion is correlated with a successful clinical outcome has been called into question by randomized trials involving instrumented spinal fusion [12,13]. The suboptimal clinical success of spinal arthrodesis and the success of total joint arthroplasty in other orthopedic subspecialties have prompted the spine community to seek an arthroplasty solution for the lumbar spine that both relieves pain and preserves physiologic motion. The theoretical advantages of a nonfusion disc arthroplasty solution are prevention of adjacent segment disease by preserving motion, protection of neural elements by restoring disc height and shorter recuperation times because patients would not require a recuperative period to allow for fusion maturation. The purpose of this review is to describe the relevant anatomy and biomechanical theory behind the designs of artificial disc prostheses. In addition, the early clinical results of prostheses currently being implanted in humans in Europe and the United States are reviewed.

## Anatomy and biomechanics

A thorough examination of the anatomy, biomechanics and motion of the normal and degenerated lumbar spine will likely predict some of the necessary requirements for the successful design of disc prostheses and should also propose indications for their successful implantation. The lumbar spine is a complex system of bone, joints, muscle, and connective tissue that provides motion for the trunk, but it also must be rigid to provide mechanical support for the body and protection for the neural elements.

A motion segment or functional spinal unit consists of two adjacent vertebrae and the intervening soft tissues of the anterior and posterior elements. Because of the combination of stability and mobility, lumbar spine motion is complex. Translation and rotation are possible in three orthogonal planes [12]. The disc is the main constraint to motion but also allows a certain amount of movement [13]. In upper lumbar motion segments, lateral bending is the predominant motion. In the lower lumbar spine and lumbosacral motion segment, flexion and extension are the prevalent motions [14]. In addition, 2 to 4 mm of anterior translation in the sagittal plane is normal for the lumbar spine vertebral bodies [12]. Further complicating design of a successful intervertebral disc is the center of rotation for each lumbar motion segment, which changes with flexion, lateral bending and rotation [15]. In addition, the movements of axial rotation and lateral bending are coupled in the lumbar spine [16]. The biomechanics of spinal motion could, therefore, necessitate a creative design to reproduce and preserve natural spinal motion. The upper lumbar spine has different motion characteristics and a successful design of a prosthesis for the L5–S1 level might not be suited for implantation in the upper lumbar spine. The intervertebral disc has a complex structure that allows motion between segments, and it is also the main constraint to motion and the primary stabilizer of the functional spinal unit.

The vertebral disc consists of an outer annulus fibrosis made up mainly of collagen. The inner nucleus fibrosis is made up of water (up to 90% in young people), proteoglycans and collagen [12]. For review of the structure and function of the intervertebral disk see Diwan et al. [17]. The anterior column (consisting of vertebral body and disc) supports most of the body weight in the upright position. However, biomechanical studies showed that the posterior elements and facet joints do support 16% of the axial load [18]. The hydrophilic nucleus pulposus generates tension in the annulus and, therefore, allows for some motion while resisting compression and loading. On loading of the intervertebral disc, its two components behave differently: with lateral bending, the annulus bulges toward the direction of motion while the nucleus slides away from the pressure [19]. Average L4–L5 motion was described by Pearcy et al. [20] in radiographic studies: average flexion 13 degree, extension 3 degrees, lateral bending 3 degrees and 0–1 degree of axial rotation. Partial removal of discs and disc degeneration alters these average motions [21].

After age 30, the nucleus gradually begins to lose water content, and the volume of the nucleus shrinks [22]. The load borne by the annulus subsequently increases and is subject to weakening and tearing; resistance to loading is diminished and disc herniation and desiccation can result [23,24]. Disc degeneration does not appear to be uniformly painful, as magnetic resonance imaging evidence of disc degeneration is commonly present among asymptomatic individuals [25]. Disc degeneration results in decreased disc height, irregular end plates, sclerosis of the disc and osteophyte formation. In addition, neural elements can be compressed or injured by disc herniation, neuroforaminal stenosis or spinal stenosis [26]. Motion at the functional spinal unit obviously changes with this degeneration. Disc degeneration can result in increased instability (eg, spondylolisthesis), but inflammation, hypertrophy and calcification of the posterior elements and surrounding soft tissues can eventually result in decreased motion.

In the lumbar region, the facet joints are oriented in the sagittal plane; therefore, they resist rotation and allow flexion and translation [27]. Physiologic lordosis allows the facet joints in the lumbar spine to bear axial loads (up to 16% in some studies [18]). Disc degeneration and disc space narrowing force the lumbar facet joints to bear increased load and likely lead to earlier degeneration [28]. Theoretically, one important advantage of disc arthroplasty is to restore disc motion and thereby preserve lumbar facet structure and function. However, results from clinical trials of disc replacement do not yet have sufficient follow-up to determine whether the cascade of facet joint arthropathy is halted.

The type of motion exhibited by each patient's lumbar spine and degree of posterior element and facet pathology