Lumbar Disk Arthroplasty for Degenerative Disk Disease: Literature Review

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Key words
- Artificial disk
- Degenerative disk disease
- Low back pain
- Lumbar arthroplasty
- Lumbar fusion
- Lumbar spine
- Total disk replacement

Abbreviations and Acronyms
ALIF: Anterior lumbar interbody fusion
ASDeg: Adjacent segment degeneration
ASDis: Adjacent segment disease
CCM: Cobalt-chromium-molybdenum
DDD: Degenerative disk disease
FDA: Food and Drug Administration
HO: Heterotopic ossification
IVD: Intervertebral disk
LBP: Low back pain
LF: Lumbar fusion
LTDR: Lumbar total disk replacement
ODI: Oswestry Disability Index
PCU: Polycarbonate urethane
PLIF: Posterior lumbar interbody fusion
RCT: Randomized controlled trial
ROM: Range of motion
TLIF: Transforaminal lumbar interbody fusion
UHMWPE: Ultra-high-molecular-weight polyethylene
VAS: Visual analog scale

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Low back pain is the principal cause of long-term disability worldwide. We intend to address one of its main causes, degenerative disk disease, a spinal condition involving degradation of an intervertebral disk. Following unsuccessful conservative treatment, patients may be recommended for surgery. The two main surgical treatments for lumbar degenerative disk disease are lumbar fusion: traditional standard surgical treatment and lumbar disk arthroplasty, also known as lumbar total disk replacement. Lumbar fusion aims to relieve pain by fusing vertebrae together to eliminate movement at the joint, but it has been criticized for problems involving insignificant pain relief, a reduced range of motion, and an increased risk of adjacent segment degeneration. This leads to development of the lumbar total disk replacement technique, which aims to relieve pain replacing a degenerated intervertebral disk with a moveable prosthesis, thus mimicking the functional anatomy and biomechanics of a native intervertebral disk. Over the years a large range of prosthetic disks has been developed. The efficacy and current evidence for these prostheses are discussed in this review. The results of this study are intended to guide clinical practice and future lumbar total disk replacement device choice and design.

INTRODUCTION

Low back pain (LBP) is the principal cause of long-term disability worldwide.[1] The most common cause of LBP is degenerative disk disease (DDD) (**Figure 1**), a spinal condition involving the natural deterioration of an intervertebral disk (IVD).[2] Treatment for DDD with conservative methods, such as physical therapy and antiinflammatory medications,[3] may be unsuccessful with ensuing pain severely curtailing quality of life. These patients may be recommended for surgical treatment.[4]

The 2 main surgical treatments for lumbar DDD are lumbar fusion (LF), the traditional standard surgical treatment for DDD, and lumbar disk arthroplasty, also known as lumbar total disk replacement (LTDR).[3,5] However, long-term studies have had contradictory views of LF, disagreeing on the significance of pain relief, reduced range of motion (ROM), and the possible increased risk of adjacent segment degeneration.[6,7] The subsequent demand for an alternative surgical treatment resulted in the development of the LTDR technique and different types of prosthetic disks.[8] The efficacy and current evidence for these prostheses are discussed in this review.

SEARCH STRATEGY AND STUDY SELECTION

Electronic searches were performed using Ovid Medline, PubMed, Cochrane Central Register of Controlled Trials (CCTR), Cochrane Database of Systematic Reviews (CDSR), ACP Journal Club, and Database of Abstracts of Review of Effectiveness (DARE) from their dates of inception to April 2017. To achieve the maximum sensitivity of the search strategy, we used the terms "lumbar fusion" AND "lumbar disc arthroplasty" AND "lumbar total disc replacement" AND "indications" AND "contraindications" AND "Charité lumbar disc" AND "Lumbar ProDisc" AND "Maverick lumbar disc" AND "LP-ESP lumbar disc" AND "M6-L lumbar disc" AND "complications" AND "degenerative disc disease" as either key words or MeSH terms. The reference lists of all retrieved articles were reviewed for further identification of potentially relevant studies, assessed using the inclusion and exclusion criteria.

Eligible studies for the present review included those in which patient cohorts underwent an LTDR procedure and the clinical and radiologic outcomes were reported. Studies that did not include complications as end points were excluded, as well as any studies that did not report sample sizes. When institutions published duplicate studies with accumulating numbers of patients or increased lengths of follow-up, only the most complete reports were included for quantitative assessment at each time interval. All publications were limited to those involving human subjects. Conference presentations, editorials, and expert opinions were excluded.

Figure 1. Degenerative disk disease in the lumbar spine between L4-L5 and L5-S1. Disk herniation, reduced disk height, and nucleus dehydration can be observed on this lateral lumbar magnetic resonance imaging scan.

All data were extracted from article texts, tables, and figures. Two investigators independently reviewed each retrieved article (D. A., J. K.). Discrepancies between the 2 reviewers were resolved by discussion and consensus.

LUMBAR FUSION

LF is designed to alleviate pain associated with DDD by removing the IVD, decompressing nerves, and fusing the vertebrae to eliminate movement.[5] This technique was first described in the 1950s[9] and is now conducted through a range of surgical approaches (**Figure 2**), such as anterior (ALIF), posterior (PLIF), and transforaminal (TLIF) lumbar interbody fusion.[10] Pedicle screws, plates, and cages filled with bone graft material or substitutes can be used to stabilize the joint, prevent any motion, and stimulate the union of the fused vertebrae,[11,12] thus replacing the mobile joint with 1 fixed bone. However, long-term studies have found various limitations of LF. Some reported complications include infection, pseudoarthrosis, and iliac crest bone graft donor site pain.[6,13] There have also been suggestions that the long-term pain relief provided is insufficient.[3,6]

The most significant issue associated with LF, however, is the possible increased risk of adjacent segment degeneration (ASDeg) and adjacent segment disease (ASDis). When radiographic changes of IVDs can be seen at adjacent levels to the surgically treated segment, this is referred to as ASDeg.[14] If the degeneration is clinically significant, where symptoms such as stenosis, radiculopathy, and instability corresponding to the observed radiographic changes develop, then it is classified as ASDis.[14] These conditions arise when vertebrae and the intervertebral joint between them are fused. This alters the biomechanics of the immediate superior and inferior joints, increasing physiologic pressures being placed on the adjacent vertebrae and IVDs.[15,16]

Incidence rates of ASDeg after TLIF, ALIF, and PLIF were found to be as high as 43.3%, 44%, and 82.6% respectively,[17-19] while ASDis had a lower prevalence of 10%, 18.3%, and 27.3%, respectively.[20-22] This is consistent with the apparent trend described by much of the evidence detailing how PLIF causes more ASDis than ALIF and TLIF.[23] Despite the absence of a specific causal relationship between LF and ASDeg, with studies unable to demonstrate that it is not simply a natural progression of the original degenerative pathology; the unnatural biomechanical changes have led to a strong demand for motion-sparing technology to combat this issue.[24]

LUMBAR TOTAL DISK REPLACEMENT

The concept of LTDR is to relieve the pain at a vertebral segment by replacing a degenerated IVD with a moveable prosthesis, which will mimic the ROM of the native IVD and thus optimally restore its functional anatomy and biomechanics.[25] Most lumbar disk replacements are implanted using an anterior approach similar to that of an ALIF.[26] Alternative approaches for accessing different