Review Article | Surgery: Orthopedics

A narrative literature review: dynamic stabilization versus fusion—is there a difference in outcomes?

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Background and Objective: Research findings concerning artificial disc replacement (ADR) and fusion surgery is conflicting in some studies. The objective of this narrative review is to evaluate and compare the effectiveness and safety of ADR versus fusion in the lumbar spine.

Methods: A comprehensive literature search was conducted using various electronic databases, including PubMed, Embase, and Google Scholar. Relevant studies published between 1990 and 2023 were included. The search terms used were "artificial disc replacement", "disc arthroplasty", "fusion", "lumbar spine", and "clinical outcomes". The included studies were critically evaluated to determine the current evidence regarding the efficacy and safety of ADR and fusion.

Key Content and Findings: The analysis of available studies indicates that both ADR and fusion procedures have shown positive outcomes in the treatment of lumbar degenerative disc disease. ADR offers advantages such as motion preservation, decreased risk of adjacent segment disease, and better range of motion compared to fusion. Furthermore, ADR results in faster recovery, reduced need for reoperation, and improved patient satisfaction. On the other hand, fusion has been well-established and has a longer history, demonstrating reliable outcomes and fusion rates. However, fusion can lead to loss of motion and increased stress on adjacent segments, potentially leading to adjacent segment disease. In relation to complication and re-operations, both techniques were comparable and had similar safety levels despite the clear differences in reported rates across different studies.

Conclusions: While both ADR and fusion have their advantages and limitations, the evidence suggests that ADR may offer potential benefits in terms of motion preservation and reduced risk of adjacent segment disease. However, further studies are needed to evaluate long-term outcomes and cost-effectiveness. Individual patient factors should also be considered when choosing between ADR and fusion, and a comprehensive evaluation should be conducted to determine the most suitable treatment option for each patient.

Keywords: Fusion; dynamic; stabilization; disc; outcomes

Received: 31 July 2023; Accepted: 02 February 2024; Published online: 25 March 2024.

doi: 10.21037/amj-23-127

View this article at: https://dx.doi.org/10.21037/amj-23-127

Introduction

Background

Lumbar degenerative disc disease (LDDD) is a prevalent condition that often leads to chronic low back pain and functional impairment (1,2). Surgical interventions are commonly used to treat LDDD when conservative treatments fail to provide sufficient relief. Two main surgical options for LDDD are artificial disc replacement (ADR) and fusion (2). ADR involves removing the degenerated disc and replacing it with an artificial disc prosthesis, while fusion involves the removal of the disc and the fusion of adjacent vertebrae using bone grafts or interbody devices (2,3). The choice between ADR and fusion for the treatment of LDDD has been a subject of debate among spine surgeons. While both procedures aim to alleviate pain and improve function, they differ in their biomechanical effects on the spine and potential long-term outcomes. ADR is designed to maintain natural segmental motion and preserve spinal flexibility, whereas fusion eliminates motion at the treated segment, aiming to stabilize the spine and alleviate pain (2,3).

Rationale and knowledge gap

Numerous studies have investigated the efficacy and safety of ADR and fusion for LDDD, and several systematic reviews and meta-analyses have been conducted to synthesize the available evidence. However, there is still a lack of consensus regarding the optimal surgical approach. Some studies have reported superior clinical outcomes with ADR, including improved pain relief, functional restoration, and patient satisfaction (4-7). These findings advocate for the preservation of segmental motion and the potential benefits of ADR compared to fusion. Nevertheless, other studies have reported comparable clinical outcomes between ADR and fusion, suggesting that both procedures can achieve similar levels of pain relief and functional improvement (8,9). These studies emphasize the importance of successful surgical techniques and patient selection to achieve optimal outcomes, rather than focusing solely on the choice between ADR and fusion.

Objective

The conflicting findings among the studies and systematic reviews can be attributed to several factors. Variations in study design, patient characteristics, surgical techniques, and outcome measures may contribute to the differences in the results (6,7). Additionally, the duration of follow-up and the assessed outcome measures may also impact the observed clinical outcomes and the detection of potential complications (6,7). In order to provide a comprehensive analysis of the current evidence regarding ADR versus fusion in the lumbar spine, this narrative review aims to synthesize the findings of existing studies and systematic reviews. By examining the collective evidence, this review will help to elucidate the comparative efficacy and safety of ADR and fusion for the treatment of LDDD, to assist in guiding clinical decision-making and patient counseling. Given the increasing prevalence of LDDD and the expanding use of surgical interventions, it is essential to critically evaluate the available evidence in order to determine the optimal surgical approach and technique. This narrative review aims to contribute and further understanding by addressing the questions: what is the current state of knowledge on ADR versus fusion in the lumbar spine? Additionally, what are some of the areas for future research? We present this article in accordance with the Narrative Review reporting checklist (available at https://amj.amegroups.com/article/view/10.21037/amj-23-127/rc).

Methods

A comprehensive literature review was conducted in a non-systematic approach. To ensure adequate analysis, multiple electronic databases, including PubMed, Embase, and Google Scholar, were extensively searched for relevant studies published between 1990 and 2023. The search terms were selected to cover the primary aspects of the research, and included the following keywords: “artificial disc replacement”, “disc arthroplasty”, “fusion”, “lumbar spine”, and “clinical outcomes”. The inclusion of studies over a wide timeframe allowed for a comparison in terms of the evolution of treatments and implants over the years, specifically for the treatment of LDDD. Studies were compiled and examined by two separate reviewers, with a main focus on outcomes. *Table 1* details the search process and used parameters.

Results

Functional outcomes in ADR versus fusion surgeries

A comprehensive review was conducted to compare the clinical outcomes between fusion and ADR in the lumbar spine. The majority of studies included in the review

Table 1 Summary of search strategy

Items	Specification
Date of search	29th July 2023
Databases and other sources	PubMed, Embase, Google Scholar
Search terms	("artificial disc replacement" OR "disc arthroplasty") AND "fusion" AND "lumbar spine" AND "clinical outcomes"
Timeframe	1990–2023
Exclusion criteria	Case studies, letters to editors, response to letters
Selection process	Two independent reviewers. Consensus reached through discussion

Table 2 Summary of VAS and ODI scores at 2-year follow up

Study	VAS at 2 years		ODI at 2 years	
	ADR	Fusion	ADR	Fusion
Sköld *et al.* 2013 (5), mean ± SD	25.4±29.8	29.2±24.6	20.0±19.6	23.0±17.0
Zigler *et al.* 2012 (8), mean ± SD	36.6±30.1	43.3±31.6	34.5±24.5	39.8±24.3
Blumenthal *et al.* 2005 (10)	31.2 (no CI)	37.5 (no CI)	26.3 (no CI)	30.5 (no CI)

VAS, visual analog scale; ODI, Oswestry Disability Index; ADR, artificial disc replacement; SD, standard deviation; CI, confidence interval.

demonstrated similar patterns of improvement in the two main clinical parameters, visual analog scale (VAS) and Oswestry Disability Index (ODI) scores, indicating significant improvements with both techniques (6). These improvements were observed at various time points compared to baseline and were maintained over the follow-up periods. Additionally, a significant proportion of patients in both groups reported satisfaction with the surgical outcomes (8). Zigler *et al.* reported that both the ADR and fusion treatment groups achieved significant improvement in ODI scores at 5 years compared with baseline (8). Furthermore, VAS pain scores decreased by approximately 48% in both groups at 5 years postoperatively. This suggests that both techniques can effectively reduce pain and improve functional outcomes in patients (8). Similar findings were reported in a Swedish randomized controlled trial, where significant differences in favor of ADR in terms of back pain, pain improvement, and ODI at 1 year were seen, which diminished at the 2-year follow-up but reappeared at the 5-year follow-up (5). ODI and VAS mean scores at 2-year follow-up are summarized from the relevant studies in *Table 2*.

In terms of functional outcomes, Blumenthal *et al.* concluded that a higher percentage of patients in the ADR group achieved full-time employment compared to the fusion group (10). Additionally, the rate of long-term disability was significantly lower in the ADR group compared to the fusion group (11). This suggests that ADR may allow patients to return to work and resume normal activities more successfully compared to fusion surgery. However, it is important to note that there are some variations in the clinical outcomes between the two techniques. Oktenoglu *et al.* reported that the ADR group had significantly higher levels of blood loss, longer operation times, and longer lengths of hospital stays compared to the posterior dynamic stabilization group (12). In contrast, Blumenthal *et al.* found that the hospital stay was significantly shorter in the artificial disc group (10). These variations may be attributed to differences in surgical approaches and techniques used in the studies.

Radiographical outcomes were also assessed in the included studies. A study conducted in Texas reported that none of the ADR cases resulted in spontaneous fusion, and the segmental range of motion (ROM) following ADR remained within the normal range (8). Oktenoglu *et al.* found comparable results in the postoperative radiographic evaluation for both ADR and posterior transpedicular dynamic stabilization (PTDS) techniques, suggesting that both systems provided spinal stability (12). McAfee *et al.* noted that ADR patients showed a significant increase in

mean flexion/extension ROM at 24 months postoperatively compared to baseline, while the control (fusion) group showed a decrease in the same parameter (13). Berg *et al.* reported different results, observing that the fusion group had lower mobility with 70% of patients showing no mobility, while 85% of ADR patients were still mobile at the 24-month follow-up (14). They also found significant differences in adjacent segments, with more translation and flexion-extension in the fusion group compared to the ADR group (14). Auerbach *et al.* analyzed the differences in ROM between ADR and fusion groups at different operative levels and found no significant differences in ROM between the two groups (15). However, they did observe reduced segmental ROM at the operative level for the fusion group, which was not observed in the ADR group (15). Oktenoglu *et al.* reported no significant differences in lumbar and segmental lordosis evaluations between the two techniques (12). Finally, Pellet *et al.* evaluated ADR in terms of spinal balance and observed a significantly increased spinosacral angle (SSA) in the ADR group, indicating a more balanced spinal position (16). In contrast, fusion using the anterior lumbar interbody fusion (ALIF) technique did not result in a significant improvement in spinal balance despite the use of a lordotic cage (16).

Complications of ADR versus fusion

Several studies have looked at the complications associated with lumbar total disc replacement, either separately or in comparison to fusion surgery. Perfetti *et al.* examined at a statewide database, including 1,368 patients, and found an 8.8% incidence of reoperation after ADR at the 2-year mark, increasing to 15.8% at 5 years, and 19.5% at 10 years (17). Reasons for subsequent surgery were evenly split between lumbar disc degeneration, disc displacement, mechanical complications, and spinal stenosis (17). In a different study out of Denmark, researchers looked at 57 patients, with a mean follow-up of 10 years, and found the rate to be about 33% (18). David retrospectively reviewed 108 patients, with follow-up spanning over 13 years (19). He identified a 10.4% re-operation rate at the index level and 2.8% for adjacent level re-operation, mostly related to symptom recurrence due to facet arthropathy, but also some related to implant migration or calcification (19). A Food and Drug Administration (FDA) trial also reported on reoperations and adverse events in the span of 24 months and found 8.4% to 10.3% in two different kinds of ADR implants, most of them caused by recurrence of symptoms or device-related issues (20). The same FDA-regulated study of 394 patients had extended follow-up to 5 years, and found the number to have risen slightly to 11.8% (21). A prospective single-center study of ADR in 181 patients, with follow-up ranging from 5 to 10 years, showed a complication rate of 14.4%, divided between 11.9% for single segment and 27.6% for two segment interventions (22). Complications were broad, relating to generalized medical issues, access or approach related, and technique or post-operative problems (22). Reoperations reached 16.0%, with reasons cited being technique or implant-related and recurrence of symptoms (22).

Park *et al.* conducted a single-center study on a Korean cohort and reported 9.3% for their reoperation rate at around 6 years following index surgery (23). Interestingly, when divided into groups of "good" and "poor" candidates, all reoperations were observed in the group of patients classified as "poor" (23). The authors reported reoperation reasons as being adjacent level disease, facet arthritis, or possible instability (23). An older study on 62 patients with a mean follow-up of 3 years, revealed a complication rate of 80.6%, frequently occurring at L4–L5 (24). The complications were split between approach-related and implant-related problems as well as recurrence of symptoms (24). When considering the number of reoperations resulting from these complications, a total of 13.9% underwent surgical intervention after the index procedure (24). In another older study by Tropiano *et al.*, 55 patients who underwent ADR were followed for about 9 years post-index surgery, and only 9% had complications related to the surgery (25). However, it is unclear if these patients required a re-operation or if they were managed conservatively (25). In a newer study on a Chinese cohort of 35 patients followed up for 11 years, authors reported that only 2 patients (5.7%) required a re-operation, while complications related to surgical approach and implant problems approached 31.4% (26). Putzier *et al.* evaluated a 53 patient cohort with an average follow-up duration of 17 years, and the authors reported a 9.0% re-operation rate primarily due to implant fracture, migration, subsidence, and persistent pain (27).

Aghayev *et al.* conducted a study using national registry data, and out of 248 patients who underwent ADR, 127 completed 5 years of follow-up, with a total complication rate of 24.6% and re-operation rate of 4.4% (28). Bisegmental procedures were always associated with a higher number of events and complications (28). A prospective cohort study of 28 patients in Australia was conducted

on a single ADR device, with follow-up for about 9 years after the index surgery, and 39.3% had to undergo revision surgery (29). Only two reasons were given for re-operation including implant failure and significant pain (29). Another Australian cohort made up of 122 patients was assessed at a single center, with an average follow-up period of 3 years, and found to have a 3.3% reoperation rate (30). Primary reasons were due to recurrence of symptoms and instability, although the authors implied that related problems existed pre-operatively and were partially responsible (30). In a separate study of 104 patients with a shorter follow-up duration of 2 years, no implant-related complications were encountered, while only 3 patients (2.8%) experienced approach-related complications (31). Siepe *et al.* carried out a study comparing ADR levels in a cohort of 99 patients who were followed for 2 years on average, and found an overall complication rate of 17.2% with a re-operation rate of 8.1% (32). As expected, complications were lower for L5–S1 (12.3%) ADR in comparison to L4–5 (18.2%) and bisegmental (30.0%) (32). Moreover, re-operation rate was lower for L4–L5 (0%) ADR in comparison to L5–S1 (7.0%) and bisegmental (20.0%) (32). Only a few intra-operative complications were reported, while post-operative problems were more commonly seen, such as poor wound healing and instability or recurrent symptoms (32).

Considering studies that compared ADR and fusion procedures, a Swedish study randomized 152 consecutive patients into the groups undergoing ADR (80 patients) and fusion (72 patients) with a follow-up of 2 years (33). Interestingly, the re-operation rate was 10% in both groups, with reasons cited most commonly being adjacent level disease in the fusion group and persistent symptoms in the ADR group (33). The complication rate in the fusion group was reported to be 21%, while the rate was around 18% in the ADR group (33). Follow-up was then extended to 5 years with a concomitant increase in total re-operations to 30.3%, with 20.0% for ADR and 41.7% for fusion (5). The FDA approved a prospective randomized multi-center study across 14 sites in the United States, out of which 133 randomized patients completed the 5-year follow-up period (11). Revision surgery due to implant failure was noted to be 8% for ADR and 16% for fusion (11). Eliasberg *et al.* conducted a discharge database review of 2,415 patients who underwent ADR and 50,462 others who underwent lumbar fusion, with a minimum follow-up of 5 years (34). In the first year after surgery, re-operations were higher in patients who underwent lumbar fusion, at 4.01 compared to 2.9% for ADR, but this eventually equalized at the 5-year point with a rate of 5.5% for lumbar fusion compared to 6.0% for ADR (34). In a separate prospective clinical trial, a total of 229 patients were randomized to receive either a ADR or a fusion, where 155 patients went on to complete 5 years of follow-up (35). Overall re-operation rate was 9.6%, with 19.1% for the fusion surgery group and 5.6% for the ADR group; however, authors noted that a significant proportion of second surgeries in the fusion group were removal of implants that did not appear to have an associated complication, which prompted an analysis of data on re-operations that were associated with complications or other convincing clinical indications, resulting in a similar re-operation rate between the ADR and fusion (35).

Discussion

The available literature suggests that both fusion and ADR can lead to satisfactory clinical outcomes in patients with lumbar spine pathology. While most studies show similar improvements in pain and functional outcomes with both techniques, some studies indicate better clinical outcomes in the ADR group. However, the findings are not consistent across all parameters assessed, and the variations in outcomes may be influenced by surgical approaches, techniques, and patient characteristics. Further high-quality research, with higher homogeneity of variables may help us to draw definitive conclusions on the difference in clinical outcomes between fusion and ADR in the lumbar spine.

In terms of complications, it appears that both ADR and fusion have a relatively similar re-operation rate with no major adverse events reported in any of the reviewed studies. The clear variability in actual rates and seemingly wide range of potential problems indicates that patient and surgeon related factors may play an important role in the frequency of complications. Based on several studies, rates can be lowered with careful patient selection on the basis of several different radiographic and clinical parameters. Additionally, bisegmental ADR was found to consistently have greater complications and re-operations when compared to single level replacements in multiple studies, which should prompt further questioning and careful consideration when offered to patients.

The comparison of ADR versus fusion in the lumbar spine demonstrates that both procedures have their own unique advantages and limitations. ADR offers the advantage of motion preservation, which allows for a more natural ROM and potentially reduces the risk of adjacent

segment disease. Additionally, ADR has shown faster recovery, reduced need for reoperation, and improved patient satisfaction. On the other hand, fusion has a longer history with reliable outcomes and fusion rates, but it may result in loss of motion and increased stress on adjacent segments, potentially leading to adjacent segment disease. The evidence suggests that ADR may be a promising alternative to fusion for certain patients with LDDD. However, further long-term studies are needed to comprehensively evaluate the outcomes, cost-effectiveness, and potential complications associated with both procedures. Additionally, individual patient factors and preferences should be considered when determining the most suitable treatment option. In patients who maintain a very active lifestyle, ADR may provide them with a reliable treatment option that can help to preserve their activity requirements. This would be in contrast to patients who are more sedentary and low demand, where fusion options may provide them with a better outlook. Ultimately, controversy remains regarding these options despite the stated treatment goals. A mixture of patient-related, surgeon-related, and social factors would all play a role in the final decision and tailored implant choice for patients.

Conclusions

Overall, this narrative review highlights the importance of a personalized approach in decision-making regarding ADR and fusion. Clinicians should carefully assess each patient's specific needs, expectations, and clinical presentation to determine the most appropriate treatment option that will optimize outcomes and quality of life. Future research should continue to explore advancements in ADR technology and techniques, aiming to refine and improve patient outcomes in the lumbar spine.

While both ADR and fusion have their advantages and limitations, the evidence suggests that ADR may offer potential benefits in terms of motion preservation and reduced risk of adjacent segment disease. However, further studies are needed to evaluate long-term outcomes and cost-effectiveness. Individual factors should also be considered when choosing between ADR and fusion, and a comprehensive evaluation should be conducted to determine the most suitable treatment option for each patient.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Mark Lambrechts and Brian Karamian) for the series "Degenerative Spine Disease" published in *AME Medical Journal*. The article has undergone external peer review.

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://amj.amegroups.com/article/view/10.21037/amj-23-127/rc

Peer Review File: Available at https://amj.amegroups.com/article/view/10.21037/amj-23-127/prf

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://amj.amegroups.com/article/view/10.21037/amj-23-127/coif). The series "Degenerative Spine Disease" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/amj-23-127
Cite this article as: Abolfotouh S, AlNouri M. A narrative literature review: dynamic stabilization versus fusion—is there a difference in outcomes? AME Med J 2024;9:8.