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Review Article

Revision Surgeries at the Index Level After Cervical Disc Arthroplasty – A Systematic Review

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Objective: To perform a systematic literature review on revision surgeries at the index level after cervical disc arthroplasty (CDA) failure.
Methods: A systematic literature review was performed according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines. Prospective studies on patients who required a secondary surgery after CDA failure were included for analysis. The minimum follow-up for these studies was 5 years.
Results: Out of 864 studies in the original search group, a total of 20 studies were included. From a total of 4,087 patients, 161 patients required a reoperation at the index level. A total of 170 surgeries were performed, as some patients required multiple surgeries. The most common secondary procedures were anterior cervical discectomy and fusion (ACDF) (68%, N = 61) and posterior cervical fusion (15.5%, N = 14), followed by other reoperation (13.3%, N = 12). The associated outcomes for those who required a revision surgery were rarely mentioned in the included literature.
Conclusion: The long-term revision rate at the index level of failed CDA surgery was 3.9%, with a minimum 5-year follow-up. ACDF was the most commonly performed procedure to salvage a failed CDA. Some patients who required a new surgery after CDA failure may require a more extensive salvage procedure and even subsequent surgeries.

Keywords: Cervical arthroplasty, Index level, Revision, Reoperations, Anterior cervical disc replacement

INTRODUCTION

Cervical disc arthroplasty (CDA) is well-acknowledged as a motion-sparing alternative to treat mild cervical degenerative disease.[1] In comparison to anterior cervical discectomy and fusion (ACDF), CDA can achieve comparable patient-reported and clinical outcomes.[2,3] Specifically, several studies have shown that CDA can improve postoperative cervical range of motion and lower the risk of adjacent segment disease.[2,3] However, to our knowledge, there is no systematic review detailing how surgeons are managing patients when CDA fails.

The reported revision rate after CDA varies widely in the literature. Although many of the randomized trials reported a low rate of secondary surgeries after CDA, as high as 15% of reoperations were documented in retrospective studies, which may due to different indications for revisions as well as differences in CDA.[4,5] Additionally, due to the lack of clear definitions for failure, such as the term revision used interchangeably for replacing a new implant, reposition of a dislocated device or even removal and then performing an ACDF, for instance, it is difficult to evaluate the characteristics of revisions after a CDA, as well as the outcome of these patients.

To address the limitations, this systematic review focuses on revision surgery after CDA. The purpose of our review is to provide a comprehensive assessment on the existing literature on the underlying reasons for CDA failure, the types of secondary procedures performed, and the associated outcomes of revision surgery.

MATERIALS AND METHODS

We performed a systematic literature review to evaluate revision surgeries after CDA. This systematic review followed the guidance of PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses).[6] The PEO frameworks used in this review were as follows: Patients: with degenerative cervical disc disease requiring surgical treatment; Exposure: cervical arthroplasty requiring a new surgical intervention at the index treated level; Outcomes: type of secondary intervention, number of reoperations, outcomes

1. Search Strategy

We reviewed PubMed for randomized controlled trials or prospective cohort studies that reported data on causes and outcome after a revision surgery for CDA. All existing studies up until April 26, 2020, were queried and reviewed. We searched for studies from the reference list of included studies and other relevant data in addition to potentially eligible studies. The first search was performed using the following keywords: "cervical arthroplasty prospective" with 864 studies. The second search was performed using the following keywords: "cervical disc arthroplasty" with 59 studies. All titles and abstracts were screened. A flow chart detailing our search selection can be seen in Fig. 1.

1) Methodological quality evaluation

All the studies were analyzed for internal validity integrity and graded for level of evidence in accordance to the Oxford Centre for Evidence-based medicine.[7]

2) Eligibility criteria

Prospective studies with a minimum follow-up of 5 years. Studies focused on patients who underwent a CDA; studies in English language; studies reporting secondary surgeries at the index level after a CDA (revision, removal, redo, explant, etc.).

2. Data Collection Process

One (AFJ) of the authors independently extracted data from the included studies using a piloted data extracted form, resolving any discrepancies through discussion with the others. The references of relevant studies were cross-checked for additional studies not identified by the electronic search.

3. Data Extraction

The following data were extracted from the included studies: number of patients, study design, follow-up period, number of revisions surgeries, and details of subsequent surgeries followed a CDA were evaluated (e.g., index vs. adjacent vs. nonadjacent levels, type of revision), and associated outcomes after revision surgery.

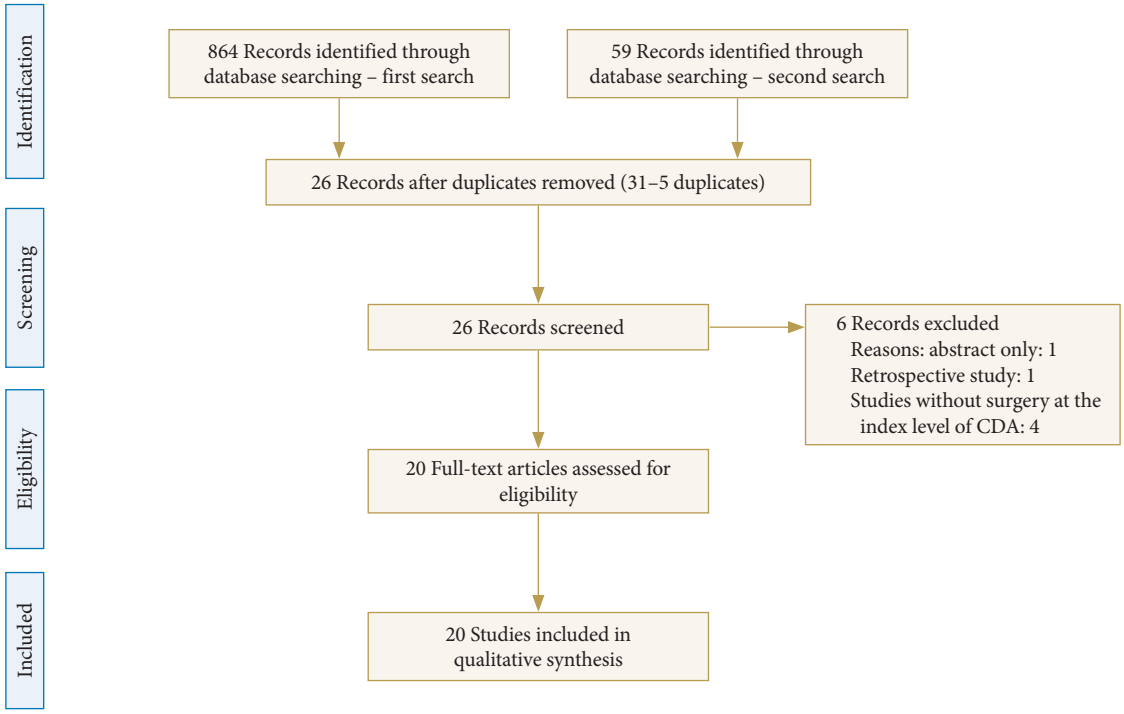

Fig. 1. Flow chart diagram of our search mechanism in accordance to the PRISMA. PubMed research September 26, 2022; first search - "cervical arthroplasty prospective" – 864 articles and second search - "revision cervical disc arthroplasty – 59 articles.

Table 1. Summary of all the data extracted from the 20 included studies

Study	Study design and device	No. of patients initially treated with CDA	Revisions surgeries at index level, at any other level or nonspecified	Procedure for revision the index level failure	Complications	Observations
Walraevens et al.,[8] 2010	Prospective cohort study single center Bryan	89 Patients	4-Year follow-up – 2 reoperated at an adjacent level (excluded) 4- to 6-year follow up – 1 reoperated at the index level and 2 at an adjacent level (3 excluded) 1 Patient operated at the index level 4 Operated on at an adjacent level			Heterotopic ossification at: 4 years – 66% HO free and 5% grade 4, 6 years – 62% HO free and 8% grade 4, 8 years – 61% HO free and 8% grade 4 Subsidence: 0.69 ± 4.5 mm at 4 years; 0.72 ± 0.59 mm at 6 years and 0.77 ± 0.69 mm at 8 years
Aghayev et al.,[9] 2013	Prospective multicenter observational case series Bryan Prestige Discocerv Scient'x Moby-C LDR Medical ProDisc-C	332 Patients	Intraoperative complication 0.6%. Two patients (0.6%) required early surgery for implant removal and fusion and hematoma evaluation. 12 (3.6%) Patients had early reintervention not specified. Early postoperative complication 7.2%	2 ACDF	37 (11%) Had ASD progression – 35 had one segment treated and 2 had 2 segments treated 15 Patients (4.6%) had a progression of distant segment degeneration – 14 with a monosegmental surgery and 1 with a bisegmental surgery – 7 were cranially and 9 caudally to the treated level	At 5 years of follow-up 40.7% had osteophytes affecting range of motion
Hacker et al.,[10] 2013	Prospective single site randomized clinical trial Bryan Prestige LP	28 Patients (Bryan)+4 additional patients 19 Patients (Prestige LP)	5 Patients had symptoms attributed to the CDA – 4 Bryan (2 patients beyond 4 years of follow-up and 2 beyond 5 years) and 1 Prestige (after 4 years of follow-up). 2 Bryan – surgical revision – 1 for device sublux-ation and subtle findings of myelopathy than an ACDF was performed – outcome was fair. 1 for kyphosis and bone deformity requiring a two level ACDF with a good outcome. 1 Prestige case had neck and arm pain with loss of vertebral body height and deformity, with HO. Device was removed with a 2 level fusion and minimal improvement. After that a third procedure was required for graft subsided, with kyphosis, corpectomy then posterior fusion – a fair outcome was reported.	3 ACDF 1 ACCF 1 PCF	2 Other Bryan with neck pain treated without surgery – haloing about their devices – 1 case 1 year later with resolution of the haloing and improvement and the other lost follow-up.	

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Table 1. Continued

Study	Study design and device	No. of patients initially treated with CDA	Revisions surgeries at index level, at any other level or nonspecified	Procedure for revision the index level failure	Complications	Observations
Zigler et al.,[11] 2013	Prospective randomized multicenter study ProDisc-C	103 Patients	2.9% of secondary surgeries at 5 years (3 at the index level due to ongoing pain without implant failures)		Implanted related adverse effects reported for 1% 11.7% of surgery-related adverse events (dysphagia, edema, dural tear, etc.)	
Burkus et al.,[12] 2014	Prospective randomized multicenter study Prestige	276 Patients	11 Patients (4.8%) had secondary surgeries at the index level. No revision surgery for adjust or modify the original implant configuration 8 Nonelective implant removals with an interbody fusion because of persistent radicular pain 11 Patients (4.6%) had a second surgery involved adjacent levels.	8 ACDF	Subsidence 12/165 patients at 60 months and 7 (4.2%) of 166 patients at 84 months 1 Patient had disc implant migration (0.5%) at the 84-month evaluation. 5 Patients (2.4%) had a broken or fractured Prestige screw	
Janssen et al.,[13] 2015	Prospective randomized multicenter study ProDisc-C	103 Initially but 86 patients were followed	7 Secondary surgeries – 7%, 6 at the index level – 5 with device removal and fusion and 1 involved a foraminotomy and posterior cervical fusion with the ProDisc left in place.	5 ACDF 1 PCF+ foraminotomy	41 Adverse events in 28 (27%) of the 103 patients – neck pain that was the most common	
Gornet et al.,[14] 2016	Prospective nonrandomized multicenter study Prestige LP 2-levels	280 Patients	Cumulative rate of secondary surgery was 9.6% at the index and adjacent level. There were 23 additional procedures: 1 revision, 14 removal, 4 supplemental fixation and 3 reoperations.	14 ACDF 4 Revision/reoperations 4 Supplemental fixation	17.5% of adverse effects related to device and surgical device surgical procedure related events, with 6.1% of serious adverse effects secondary to device	13% of HO at 84 months
Hisey et al.,[15] 2016	Prospective randomized multicenter study Mobi-C	164 Patients	8 Patients (4.9%) had a subsequent surgery 1 Patient had a laminectomy at the index level, 4 cases had a fusion and removal of the implant (2 of these 4 had also a third surgery to revise the ACDF). Finally, 3 patients (1.83%) had surgery at the adjacent level.	1 Laminectomy 4 ACDF	Radiographic failure (defined as spontaneous fusion with radiographic evidence of bridging bone across the disc space and less than 2° of angular motion on flexion/extension) occurred in 5.5% of the patients	Reasons for fusion at the index level: oversized implant, development of heterotopic ossification causing pain and kyphosis due to malpositioned device

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Table 1. Continued

Study	Study design and device	No. of patients initially treated with CDA	Revisions surgeries at index level, at any other level or nonspecified	Procedure for revision the index level failure	Complications	Observations
Jackson et al.,[16] 2016	Prospective randomized multicenter clinical trial Mobi-C One or 2 levels	260 Patients 1 level 234 patients 2 levels	4.5% Subsequent surgery for 1-level 7.3% Subsequent surgery for 2-level 3.4% (6/179) Revision at the index level 1-level group 4.7% (11/234) Revision at the index level 2-level group	2 ACDF 1 ACDF + posterior fusion	Some patients required multiple subsequent surgeries: 1 had a TDR removed than an ACDF at the index level, and finally a three level fusion. 1 Had a TDR removed then 2 level fusion and finally a revision fusion with foraminal decompression 1 Patient had removal of the 2 TDR with a fusion, requiring an anterior fusion followed by a combined fusion later 1 Patient had a TDR removed after a motor vehicle accident	
Radcliff et al.,[17] 2016	Prospective randomized multicenter study Mobi-C	225 Patients	16 Secondary surgeries (7.1%, 16/225) – 9/225 (4%) in the index level and 7/225 (3.1%) at adjacent levels		10 Patients (4.4%) had potentially device-related serious adverse events – with 4 cases of implant malposition	
Dejaegher et al.,[18] 2017	Prospective cohort study single center Bryan	89 Patients	7 Patients (8%) had 8 additional spine surgery to treat persistent symptoms – 6 radiculopathy and 1 myelopathy – 2 (2%) at the index level and 5 (6%) at an adjacent levels 14 Patients treated non-surgically for pain – 12 solved and 2 were symptomatic but did not have a new procedure 2nd surgery at the index level – 2 patients had their prosthesis removed. Adjacent level surgery – 3 patients had a 2nd Bryan implanted, one of them receiving a later laminoforaminotomy later. 2 Patients had a fusion due to bridging osteophytosis and kyphosis.		21 Patients (24%) had new or recurrent radiculopathy or myelopathy 186 Adverse effects during follow-up in 73 patients – 34% pain problems (neck, shoulder or arm), 25% pain in the hip, leg, knee or low back.	
Lanman et al.,[19] 2017	Prospective randomized multicenter study Prestige LP 2-levels	209 Patients	4.2% of secondary surgeries at the index level (8 patients 10 surgeries) – one removal after 40 days postoperatively due to arm pain and the other at 1.3 years due to cervical kyphosis. Other removals between 1.7 to 4.5 years due to foraminal stenosis, degenerative changes (2 cases), failed arthroplasty and loosening of hardware after a motor vehicle accident 6.5% of second surgeries at adjacent levels	8 ACDF	3.2% of serious adverse effects (grade 3 or 4) – implant or surgical procedure associated 11.9% of grade IV HO	

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Table 1. Continued

Study	Study design and device	No. of patients initially treated with CDA	Revisions surgeries at index level, at any other level or nonspecified	Procedure for revision the index level failure	Complications	Observations
Mehren et al.,[20] 2017	Prospective cohort study ProDisc C	50 Patients 27 (57.4%) 1 level; 17 (36.2%) 2 levels, and 3 (6.4%) with 3 levels	No surgery for symptomatic adjacent level Three patients underwent spine infiltrations for neck pain. Two patients required a fusion due to intraoperative fractures of the posterior vertebral wall and 1 patient was reoperated one year after surgery due to neck pain.	2 ACDF	No prosthesis dislocations One case – significant subsidence after a motor vehicle accident (non-operative management) 13 (35.7%) of adjacent segment degeneration (10 cranial and 3 below the index level)	HO at 10 years: grade 0, 10%; grade 1, 10%; grade 2, 22%; grade 3, 32%, and grade 4, 26%
Radcliff et al.,[21] 2017	Prospective randomized multicenter study Mobi-C	164 Patients (1 level) 225 Patients (2 levels)	1 Level: subsequent surgeries at the index level was 3% (5/164 – 4 removal, 1 reoperation) for persistent radiculopathy and neck pain (3) 1 Malpositioned implant required additional surgery 1 Gross motion due to over distraction and oversized implant requiring a fusion 3.7% (6/164) Required surgery for at least one adjacent level 2 Levels: subsequent surgeries at the index level was 4.4% (10/225 – 5 removal, 2 reoperation, 2 revision, and 1 supplemental fixation) for persistent radiculopathy and neck pain (7), and 4.4% (10/225) at the adjacent level.	9 ACDF 5 Reoperation 1 Supplemental fixation	5.3% (12/225) of patients had adverse events for 2-level and 6.1% (10/164) for one level.	A bridging bone at either level was presented in 11.1% (12/108) of patients for 1-level A bridging bone at either level was presented in 11.1% of patients for 2 levels 1 Level: 40.4% of ASD in the superior level and 43.8% in the inferior level 2 Levels: 37.5% of ASD in the superior level and 30.3% in the inferior level
Sasso et al.,[22] 2017	Prospective randomized single-center study Bryan	22 Patients	9% (2 patients) Required reoperation – one at an adjacent level and a second at a nonadjacent level (ACDF used for both)	2 ACDF	No details of complications	Three patient were converted intraoperatively to an ACDF – severe disc degeneration, small disc space and inadequate visualization of the index level (C67)
Coric et al.,[23] 2018	Prospective randomized multicenter study MoM TDR Kineflex C	136 Patients	8% of revision surgeries at the index level (11 patients) 7 Patients (5.1%) – device related 4 Patients (3%) probably device related		1.4% Device migration 1.4% Subsidence 14.3% of radiolucency HO with a bridging across the disc space in 2.9% of the cases	No details of outcome after reoperations or details of the technique used for reoperation

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Table 1. Continued

Study	Study design and device	No. of patients initially treated with CDA	Revisions surgeries at index level, at any other level or nonspecified	Procedure for revision the index level failure	Complications	Observations
Vaccaro et al.,[24] 2018	Prospective nonrandomized and randomized multicenter study Secure-C	89 Patients nonrandomized and 151 randomized patients	10 Surgeries at the index level (4.2%) at 7 years postoperative – 6 removals and 4 posterior decompressions without removal of the device 10 Surgeries at adjacent levels (4.2%)	6 ACDF 4 Posterior decompression		62.3% of patients had symptoms possibly related to adjacent level
Lavelle et al.,[25] 2019	Prospective randomized single-center study Bryan	242 Patients	Serious adverse effects 4.1% - 8 cases - 1 reported implant loosening, 1 mal-positioned implant, 1 excessive neck/ arm pain, and 5 spinal events (all the 8 at the index level with three requiring implant removal)	3 ACDF		
Gornet et al.,[26] 2019	Prospective randomized multicenter study Prestige LP 2-levels	209 Patients	Cumulative rate of secondary surgery was 4.7% (9 patients) at the index level (six removal, 2 supplemental fixation and 3 reoperation) and 9% at adjacent levels	6 ACDF 2 Supplemental fixation 3 Reoperation		Cumulative rate of serious adverse effects (grade 3 and 4) associated with implant were 3.8% patients through 10 years Rate of HO grade III and IV 39%
Dufour et al.,[27] 2019	Prospective cohort multicenter study Mobi-C	384 Patients with 535 prostheses	1.5% of reoperation at the index level – 6 of 384 – device removal or repositioning. 2.9% of surgery at adjacent levels – 11 patients – 4 for new symptomatic ALD and 7 had already an ADD minor before surgery		Complication rates: 34 patients (8.9%) had 41 adverse events (device-surgery related with/ without reoperation)	Grade 4 HO - 16.4% of the implanted segments had ossification with complete fusion; grade 3 in 6.8%, grade 2 in 39.4%, grade 1 in 14.4%, and grade 0 in 22.9%. Distal and proximal adjacent degeneration occurred in 42.2% and 39.1% of patients.

HO, heterotopic ossification; ACDF, anterior cervical discectomy and fusion; ASD, adjacent segmental degeneration; ACCF, anterior corpectomy and fusion; PCF, posterior cervical fusion; TDR, total disc replacement; ADD, adjacent disc disease.

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RESULTS

1. Study Selection

A total of 20 studies were included. There were 10 prospective randomized multicenter studies (level 1 of evidence), 3 prospective randomized single-center studies (level 1 of evidence), and 7 prospective cohort studies (level 2 of evidence). A total of 4,087 patients were included.[8-27] Follow-up rates, when documented, varied from 54% to 92%, with the exception of the study by Walraevens et al.[8] which had only 26 of 89 patients with a follow-up at 8 years (29.2%). All the information extracted from the studies are summarized in Table 1.[8-27]

2. Reoperation at the Index Level

There were 161 patients who had at least 1 reoperation at the index level. The reoperation rate was 3.9% with a minimum 5-year of follow-up. Of note, these 161 patients had 170 surgeries, as some of them had one or more revision procedures.

3. Procedure for Reoperation the Index Level

In the majority of the studies, the procedure performed was not clearly described. When "removal" was mentioned in the studies, we inferred that an ACDF was performed after removal of the device. When reoperation/ revision was mentioned, we inferred that the CDA was replaced by another implant or the patients had the implant repositioned, but a fusion was not performed, as many authors used the terms "removal" and "revision" in the same study with different meanings.

When mentioned in the study results (90 patients), the revision procedures performed were: ACDF/removal: 61 (68%); supplemental fixation/posterior cervical fusion: 14 (15.5%); reoperation/revision: 12 (13.3%); posterior decompression/laminectomy: 2 (2.2%); anterior cervical corpectomy and fusion: 1 (1.1%). Of note, the levels of revision procedures included were not always mentioned, but some of them involved additional levels.

Of note, Sasso et al.[22] did not have a revision surgery at the index surgery after the procedure, but 3 of the 242 patients who were planning to have a CDA required an intraoperative ACDF due to severe disc degeneration, small disc space, and inadequate visualization of the index level (C67). We considered this as a failure CDA at the index level.

4. Reasons for Reoperation at the Index Level

Interestingly, information about a patient's outcome after revision surgery at the index level was rarely described in the included studies. An exception to this was Hacker et al.,[10] who reported the outcomes of 3 patients: one had a Bryan disc subluxation and subtle findings of myelopathy and underwent an ACDF with a fair outcome. Another had local kyphosis after a Bryan disc and subsequently underwent a 2-level ACDF with a good outcome. Finally, a patient with a Prestige cervical disc had neck and arm pain, and loss of vertebral height and deformity. This patient required CDA removal and underwent a 2-level fusion, but the grafts subsided causing marked kyphosis requiring an additional procedure: a corpectomy and posterior fusion – with a fair outcome according to the authors.

The following indications for revision surgeries at the index level were documented: progressive symptoms/ongoing neck or arm pain (the most common cause described), disc subluxation, segmental deformity, myelopathy after surgery, ossification causing pain and kyphosis, oversized implant, intraoperative fractures of the posterior vertebral wall, malpositioned implant.[10,11,12,13,19,20,21]

DISCUSSION

In our review, we focused on high-quality studies discussing secondary surgery at the index level after a failed CDA. Most of the specific literature about CDA is about its safety and even superiority in clinical outcomes when compared with ACDF, as well as its potential to preserve motion. However, there is a paucity of data on the indications for reoperation, as well as the outcome of this group of patients, which are of paramount importance for patient counseling preoperatively.

Park et al.[28] performed a retrospective evaluation of 21 patients who underwent a revision surgery after a CDA and had a minimum 2-year follow-up. In the primary procedure, 14 patients had a single level CDA, 2 patients had a 2-level CDA and 5 patients had 2-level hybrid surgery. The reasons for revision surgery were as follows: 17 (80.9%) were revised by poor patient selection according to them (such as severe cervical spondylosis or ossification of the posterior longitudinal ligament), 7 by insufficient decompression (35%), and 7 by implant malposition (35%), with 6 (28.5%) subsidences, 3 osteolysis (14.25%) and 1 postoperative infection (4.7%). To treat these failures, 16 patients had their CDA removed followed by 1-level ACDF (N = 11), 2-level ACDF (N = 3), 1-level corpectomy (N = 1), posterior laminoforaminotomy and fusion (N = 3), and combined procedures due to infection and osteolysis (N = 2). Using Odom's scale, 86% of the patients were satisfied in the final follow-up. Similarly, with the results of our review, ACDF was the most commonly used salvage procedure following CDA failure, but

it may include additional levels or supplementary posterior cervical surgery, increasing the morbidity of the procedure and potential complications. Interestingly, proper patient selection may decrease the reoperation rates. As stated in the study of Park et al.,[5] CDA is not appropriate for all cases. Instead, CDA should be considered for those with preserved disc height, less severe degenerative disease, without spinal instability or deformities (such as kyphotic configuration of the segment) and osteoporosis.[29]

The outcome of revisions procedures has rarely been studied. Only Hacker et al.[10] reported the outcomes, with fair results in 2 of 3 cases, requiring more complex salvage procedures. Additionally, the time for reoperation is quite variable in the literature. Zigler et al.[11] reported 30 (5.6%) reoperations in 535 patients who had a CDA using the ProDisc-C. The mean time for reoperation was 78.3 months, ranging from 24 to 181 months. They also reported no surgeries for device failure. In our review, the terms used in the studies were not also clear. For instance, some authors used the term "removal," which we inferred that an ACDF was used instead. Revision or reoperation may be used interchangeably, for drainage a hematoma or to replace the CDA or even repositioning the implant. For this reason, a detailed analysis is limited. The U.S. Food & Drug Administration defines revision surgery as a procedure that adjusts or modifies the original implant configuration; removal surgery as a procedure that removes one or more components of the original implant and replacement by a different type of implant.[30,31] The misuse of these terms may lead to a wrong interpretation of the types of subsequent surgeries.

The reoperation rate at the index level obtained in our review was 3.9%, with the most common salvage procedure being an ACDF (68%). Skovrlj et al.[31] discussed the options for a failed CDA. They proposed that, for infection, extrusion, malposition, subsidence, or retropulsion, the most reasonable option is to remove the implant and perform an ACDF. In cases where there is excessive bone removal of 1 or even 2 vertebral bodies, a 1- or 2-level corpectomy may be necessary, which may increase the morbidity of the procedure. Additionally, if by any reason a plate is not possible, posterior fixation may be also considered. For patients who had radiculopathy with foraminal stenosis, a posterior decompression (with or without fusion) is an option. Of note, salvage procedures increase the risk of complications and may be potentially associated with a less favorable outcome. In our review, we found reoperations for all the reasons reported by Skovrlj et al. with exception of infection.

Our study is limited by the lack of specific and high-quality studies evaluating revision surgeries at the index level – the included studies did not focus on revision at the index level. The use of only PubMed database for searching clinical studies may reduce the number of included articles. Another limitation is the unclear use of the terms revision and removal in the studies, not always clear enough leading to potential bias in the interpretation of the types of subsequent surgeries. Finally, the heterogeneity in the data presentation and the low level of details, such as lack of final outcome for revision patients, may weaken our final interpretation. However, the results provide useful insight on CDA reoperations and the need for studies focusing on outcomes after revision CDA.

CONCLUSION

We report a reoperation rate of 3.9% after a long-term follow-up after a primary CDA. ACDF was the most common procedure to salvage a failed CDA. Some patients with CDA failure may require a more extensive salvage procedure and even subsequent surgeries. Future prospective studies addressing specifically the management and outcome of patients who failed a CDA are necessary.

CONFLICT OF INTEREST

The authors have nothing to disclose.

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