



Outcomes After Cervical Disc Arthroplasty Versus Stand-Alone Anterior Cervical Discectomy and Fusion: A Meta-Analysis

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Abstract

Study Design: Systemic review and meta-analysis.

Objectives: To review and compare surgical outcomes for patients undergoing stand-alone anterior cervical discectomy and fusion (ACDF) versus cervical disc arthroplasty (CDA) for the treatment of cervical spine disease.

Methods: A systematic search was performed on PubMed, Medline, and the Cochrane Library. Comparative trials measuring outcomes of patients undergoing CDA and stand-alone ACDF for degenerative spine disease in the last 10 years were selected for inclusion. After data extraction and quality assessment, statistical analysis was performed with R software *metafor* package. The random-effects model was used if there was heterogeneity between studies; otherwise, the fixed-effects model was used.

Results: In total, 12 studies including 859 patients were selected for inclusion in the meta-analysis. Patients undergoing stand-alone ACDF had a statistically significant increase in postoperative segmental angles (mean difference 0.85° [95% confidence interval = 0.35° to 1.35°], $P = .0008$). Patients undergoing CDA had a decreased rate of developing adjacent segmental degeneration (risk ratio = 0.56 [95% confidence interval = -0.06 to 1.18], $P = .0745$). Neck Disability Index, Japanese Orthopedic Association score, Visual Analogue Scale of the arm and neck, as well as postoperative cervical angles were similar between the 2 treatments.

Conclusions: When compared with CDA, stand-alone ACDF offers similar clinical outcomes for patients and leads to increased postoperative segmental angles. We encourage further blinded randomized trials to compare rates of adjacent segmental degeneration and other postoperative outcomes between these 2 treatments options.

Keywords

anterior cervical discectomy and fusion, ACDF, cervical disc disease, cervical disc arthroplasty, cervical disc replacement, stand-alone ACDF, meta-analysis

Introduction

Rationale

Anterior cervical discectomy and fusion (ACDF) was first described by Smith and Robinson in 1958, and it is one of the most widely used surgical procedures performed by spine surgeons.^{1,2} It is the standard treatment for cervical degenerative disc disease causing radiculopathy and myelopathy.³ Goals of performing ACDF are to improve the patient's pain, spinal stability, neurological function, and cervical lordosis.

However, this procedure is not without complications. Placing interbody devices with anterior plate fixation has been

shown to cause dysphagia by disrupting tissue anterior to the vertebra and also leads to long-term adjacent segmental degeneration (ASD) as the plate causes rigid fixation at the vertebrae

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above and below the level of fusion.⁴⁻⁹ Because of these issues, stand-alone ACDFs have gained popularity in the past decade, where interbody devices are inserted and internally fixated without the addition of an anterior plate. By avoiding the use of an anterior plate, complications associated with the plate can theoretically be eliminated while still achieving the same goals of bony fusion for the patient.^{7,10,11}

In another widely used method of treating degenerative spine disease, cervical disc arthroplasty (CDA) with placement of a disc prosthesis has a lower risk of ASD and dysphagia compared with traditional ACDF since it requires no attachment of an anterior plate and allows for maintenance of motion across the spinal level.^{12,13} This treatment is highly advantageous for the patient, as it better preserves the range of motion and mobility of the index level and may prevent the need for future revision surgeries for adjacent-level breakdown.¹³⁻¹⁵

Objectives

This meta-analysis aimed to compare the novel technique of fusion with stand-alone devices to CDA by comparing segmental angles, cervical angles, rates of ASD, rates of dysphagia, blood loss, and operative time. Clinical outcomes among patients as measured by Neck Disability Index (NDI), visual analogue scale (VAS) of the arm and neck, and Japanese Orthopedic Association (JOA) scoring systems were also compared. This study was performed under the standards of the Preferred Reporting Items for Systemic Reviews and Meta-Analyses.^{16,17}

Methods

Search Protocol and Information Sources

This meta-analysis was conducted according to the guidelines set by PRISMA.¹⁶ We searched the databases of Medline, PubMed, and the Cochrane Database of Systemic Reviews. Our search term included the phrase: (((“cervical”) AND (“zero-profile” OR “integrated” OR “self-locking” OR “anchored” OR “stand-alone”)) OR (“disc”) AND (“replacement” OR “artificial” OR “arthroplasty”) AND (“cervical”))) as a search term in all fields for all 3 databases. Articles found with this search were reviewed according to our selection criteria. References of the articles eventually selected for inclusion in our meta-analysis were also screened for possible inclusion.

Eligibility Criteria, Study Selection, and Data Items

This meta-analysis included studies with the following criteria: (1) compared patients who had undergone ACDF with only an interbody device and without anterior plating to patients that had undergone CDA for the treatment of degenerative spine disease; (2) reported one of the following measures: measurements of cervical angle, measurements of segmental angle, ASD, dysphagia, operative time, blood loss, VAS arm, VAS neck, JOA score, and NDI score. Stand-alone ACDF was defined as any fusion that did not consist of an anterior plating mechanism.

We excluded editorials, case reports, conference papers, letters to the editor, abstracts, and literature reviews. Only articles that were written in the English language and published in the last 10 years were included. The authors used Covidence (Veritas Health Innovation Ltd, Melbourne, Australia) for systemic review management software to assist with screening and review organization.

Data Collection Process and Risk of Bias in Individual Studies

Articles from the initial search were screened by 2 authors (JG, PP) for their suitability for inclusion. This process was in accordance to the checklist provided by the Meta-analyses Of Observational Studies in Epidemiology (MOOSE) checklist promoted by Cochrane for ensuring systemic review quality.¹⁸ Each study included in the meta-analysis was thoroughly examined and assessed for the possibility of bias. Data was collected from the text, tables, graphs, and supplementary material provided in the articles by the same authors who performed the screening. In the event of any disagreement with decisions of study inclusion or data extraction, a third author made a final decision (AH).

Summary Measures, Synthesis of Results, and Risk of Bias Across Studies

When mean or standard deviation values were not available in the publications, an effort to retrieve this missing information from the corresponding authors of each study was made. If we were unable to reach the authors and obtain the data, we used statistical methods described in previous literature to derive the needed numerical values. For studies that reported mean and range (as opposed to mean and standard deviation), standard deviation was estimated using a method previously described.¹⁹ When studies reported median with interquartile range or range, formulas suggested by Wan et al were used for estimation.²⁰ If accurately estimating the value was not possible, we excluded the study from the meta-analysis.

Statistical analysis and visualization were performed with R software (The R Foundation, Vienna, Austria) using the *metafor* package.^{21,22} The Cochran Q statistic and I^2 statistic were reported to assess heterogeneity among studies. A random-effects model was used when I^2 was greater than 50%. In other cases, a fixed-effects model was used. Risk ratio (RR) and 95% confidence interval (CI) were reported for binary outcomes (postoperative ASD, dysphagia) while mean difference and 95% CI were reported for the rest of the continuous outcomes. Publication bias was also assessed using funnel plots of the data generated from the *metafor* package.

Results

Study Selection and Risk of Bias Within Studies

The database search yielded 3301 results from PubMed, 3248 from Medline, and 661 from Cochrane Library. Screening of

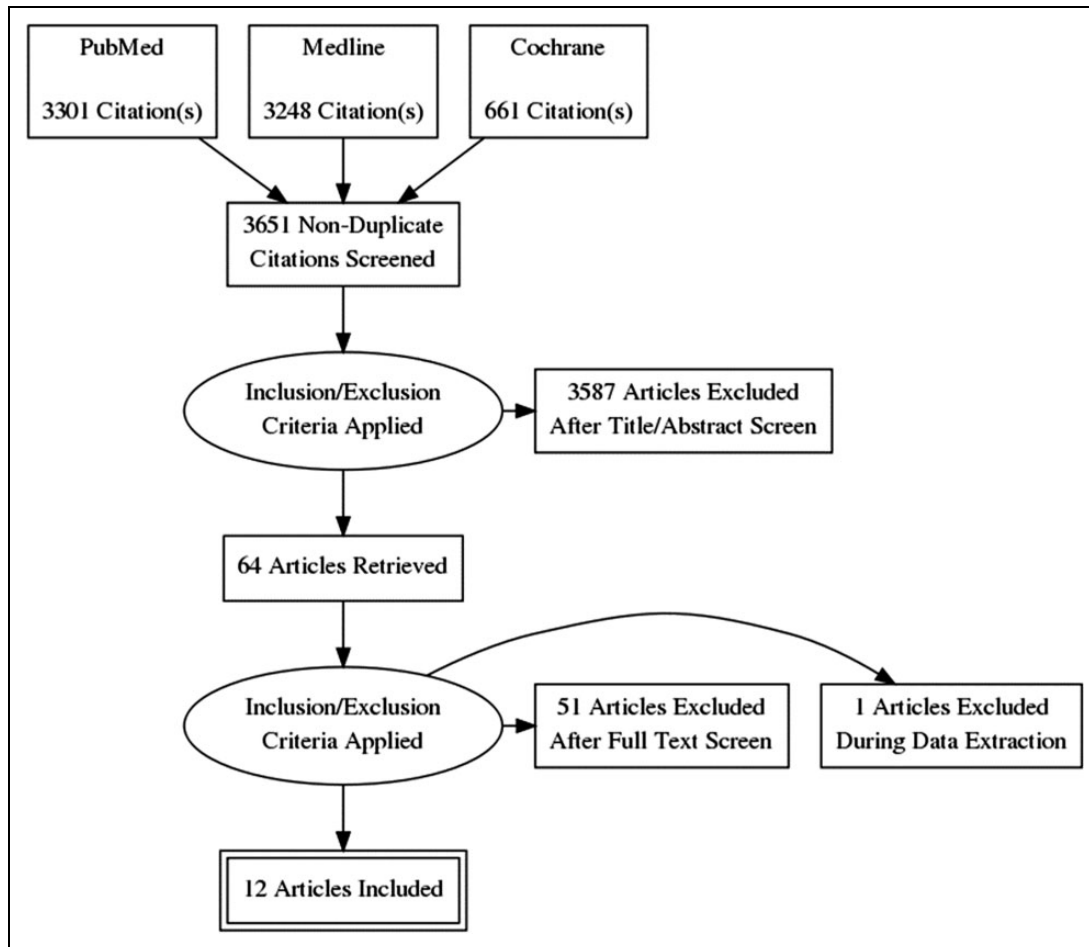


Figure 1. PRISMA flowsheet. PRISMA flowsheet illustrating the number of articles excluded at different stages of the screening process.

the titles and abstracts revealed 64 articles, which were assessed for inclusion in our meta-analysis by full text screening. After applying exclusion criteria, 12 total studies were included in our study,²³⁻³⁴ which were included in our quantitative analysis. A PRISMA flow sheet for our meta-analysis is displayed in Figure 1.

Descriptions of each study including location, design, measured outcomes, and length of follow-up are displayed in Table 1. Each study was thoroughly screened for quality according to MOOSE criteria for suitability for data extraction. Results of the quality screen are displayed in Supplement 1, available online. Review of the reference sections in the 12 studies initially selected for inclusion yielded no additional studies to be included.

Study Characteristics

The meta-analysis included a total of 859 patients, and 411 patients underwent CDA while 448 underwent cervical stand-alone ACDF. Artificial disc prostheses used for the procedures in the studies included in this meta-analysis were the Bryan disc (Medtronic, Memphis, TN), Discover prosthesis (DePuy Spine, Inc, Raynham, MA), ProDisc-C (DePuy Synthes Spine,

Raynham, MA), Mobi-C (Zimmer Biomet, Warsaw, IN), and Prestige (Medtronic, Memphis, TN) or was not specified. Stand-alone interbody devices used in the included studies, when specified, included the Brantigan cervical I/F (DePuy Spine, Inc, Raynham, MA), Zero-P (DePuy Synthes Spine, Raynham, MA), Cervios (DePuy Synthes Spine, Raynham, MA), Solis (Stryker Spine, Allendale, NJ), MC+ (Zimmer Biomet, Warsaw, IN), and Shell (Advantage Manufacturing Technologies Company, Nonnweiler, Germany). Only one study²⁷ measuring NDI scores included both single- and 2-level patients, and was included in this meta-analysis. All other studies were single-level studies. All revision operations were excluded in this meta-analysis. Patient demographics including sample sizes, gender, mean ages, and descriptions of surgical procedure for each individual study is provided in Table 2.

Synthesis of Results

Radiological Outcomes. Segmental angles were reported in 6 studies^{23,25,26,29,31,33}; however, only 4 studies were included^{23,25,26,31} because standard deviation values were not reported in the other 2 studies.^{29,33} Among the included studies, segmental angles ranged between 3.7° and 6.4° in stand-alone

Table 1. Study Characteristics Including Country, Study Design, Outcomes Measured, and Mean Follow-up Time.

Study	Country	Design	Outcomes Measured	Mean Follow-up (Months)
Donk et al ²³	Netherlands	Randomized prospective	Cervical angle, segmental angle	25.4 ± 18.4
Donk et al ²⁴	Netherlands	Randomized prospective	NDI, dysphagia	Median = 106.8
Shi et al ²⁵	China	Nonrandomized prospective	Cervical angle, segmental angle, operative time, blood loss, dysphagia	<1 (2 days postoperatively)
Shi et al ²⁶	China	Retrospective	ASD, cervical angle, JOA, NDI, segmental angle, operative time, blood loss, dysphagia	24
Vorsic and Bunc ²⁷	Slovenia	Nonrandomized prospective	NDI	12
Qizhi et al ²⁸	China	Randomized prospective	ASD, cervical angle, JOA, NDI, operative time, blood loss, dysphagia	32.4
Lee et al ²⁹	Korea	Not described	ASD, cervical angle, VAS neck, VAS arm, NDI, segmental angle	CDA 43.4, stand-alone ACDF 44.6
Park et al ³⁰	Korea	Retrospective	ASD, cervical angle, VAS neck, VAS arm	CDA 28 ± 5.0, stand-alone ACDF 30 ± 5.8
Röllinghoff et al ³¹	Germany	Retrospective	ASD, VAS neck, VAS arm, segmental angle, dysphagia	17.5
Park et al ³³	Korea	Retrospective	Cervical angle, NDI, segmental angle, operative time	CDA 20, stand-alone ACDF 22
Bhadra et al ³⁴	United Kingdom	Nonrandomized prospective	VAS neck, VAS arm, operative time	Not specified
Sundseth et al ³²	Norway	Randomized prospective	VAS neck, VAS arm, NDI, operative time, blood loss, dysphagia	24

Abbreviations: NDI, Neck Disability Index; ASD, adjacent segmental degeneration; JOA, Japanese Orthopedic Association; VAS, Visual Analogue Scale; CDA, cervical disc arthroplasty; ACDF, anterior cervical discectomy and fusion.

ACDF and between 1.8° and 5.5° in CDA at final follow-up. Meta-analysis indicated a mean difference of 0.85° (95% CI = 0.35° to 1.35°, $P = .0008$) with patients undergoing stand-alone ACDF having a higher mean postoperative segmental angle. All studies included in the meta-analysis for segmental angles were of single-level disease only. A total of 2 studies specified upright radiographic images,^{23,26} whereas 2 studies did not specify imaging protocol in their publications.^{27,33} A forest plot of segmental angle results is provided in Figure 2.

There was not a statistically significant difference in mean postoperative cervical angles described in 5 studies measuring single-level disease^{23,25,26,28,30} after 2 studies were excluded for incomplete data.^{29,33} Meta-analysis revealed a mean difference of -1.03° (95% CI = -3.12° to 1.05°, $P = .3308$) for postoperative cervical angle indicating that CDA had a slightly higher cervical angle.

Adjacent Segment Degeneration. Measurements of ASD after surgery were reported by 5 studies^{26,28-31} ASD was shown to be decreased in the patients undergoing CDA compared with stand-alone ACDF by an amount that was close to statistical significance. The log risk ratio was found to be 0.56 (95% CI = -0.06 to 1.18, $P = .0745$) when comparing CDA to stand-alone ACDF for incidence of ASD. Data results for ASD are displayed as a forest plot in Figure 3.

Dysphagia. A total of 6 studies included data on dysphagia outcomes, but 1 study was excluded from our meta-analysis as its results were reported as a median value instead of events out of total sample size.³² In the included studies,^{24-26,28,31} dysphagia

appeared to be decreased in patients undergoing CDA when compared with stand-alone ACDF with a log risk ratio of 0.32 (95% CI = -0.21 to 0.84, $P = .2368$). However, this was not statistically significant. Analysis results for dysphagia are displayed as a forest plot in Figure 4.

Blood Loss. Blood loss was found to be slightly increased in the stand-alone ACDF treatment after measuring the variables from 4 studies.^{25,26,28,32} There was a mean difference of 3.26 mL (95% CI = -5.39 to 11.91, $P = .4600$).

Operative Time. Operative time was reported by 5 studies,^{25,26,28,32,34} and stand-alone ACDF had less operative time with a mean difference of -2.94 minutes (95% CI = -13.12 to 7.24, $P = .5715$).

Clinical Outcome Scores. NDI scores were reported in 7 studies.^{24,26-29,32,33} One study was excluded for absent standard deviation values,³³ and a total of 6 studies were included. Studies rated the NDI scores on a scale of 0 to 50. One study included NDI scores out of 100, and this was converted to a scale of 50 to be standardized with other articles.³² One study included both single-level and multilevel treatments. This meta-analysis revealed no statistically significant difference in NDI scores between the CDA and stand-alone ACDF as shown in Figure 5. Results revealed a mean difference of -0.16 (95% CI = -0.53 to 0.20, $P = .3749$) between the 2 treatments.

Independent VAS for both arm and neck were measured in several studies included in our meta-analysis.²⁹⁻³² Two studies

Table 2. Demographics of Patients Included in Our Meta-Analysis for Each Study.

Study	Sample Size (N)			Number of Females			Mean Age		Fusion Device	Arthroplasty Prosthesis
	Total	Stand-Alone ACDF	CDA	Total (%)	Stand-Alone ACDF	CDA	Stand-Alone ACDF	Arthroplasty		
Donk et al ²³	97	47	50	48 (49%)	22	26	52.2 ± 8.1	53.6 ± 6.9	Not specified	Not specified
Donk et al ²⁴	95	46	49	48 (51%)	22	26	43.1 ± 7.5	44.1 ± 6.4	Autologous bone	Brantigen cervical I/F Device
Shi et al ²⁵	112	57	55	45 (40%)	20	25	50.6 ± 7.2	48.9 ± 7	Excised osteophytes and beta-tricalcium phosphate	Zero-P Device
Shi et al ²⁶	128	68	60	71 (55%)	35	36	47.4 ± 7	46.5 ± 6.8	Packed local excised bone and beta-tricalcium phosphate	Zero-P Device
Vorsic and Bunc ²⁷	77	38	39	55 (71%)	28	27	51.3 ± 8.1	48.1 ± 8.1	ChronOS	Cervios
Qizhi et al ²⁸	30	16	14	10 (33%)	5	5	48.13 ± 5.98	46.79 ± 5.15	Not specified	Zero-P Device
Lee et al ²⁹	42	28	14	6 (14%)	4	2	53.6	47.1	Allograft	Solis
Park et al ³⁰	33	18	15	NA	NA	NA	53 ± 9	45 ± 11.7	Allograft	MC+
Röllinghoff et al ³¹	42	23	19	20 (48%)	10	10	50.3 ± 11.2		Hydroxyappetite paste	Shell
Park et al ³³	53	32	21	22 (42%)	12	10	47	45	Iliac bone harvest	Solis
Bhadra et al ³⁴	30	15	15	13 (43%)	7	6	38	34	Tricortical bone graft from iliac crest	Brantigan
Sundseth et al ³²	120	60	60	73 (61%)	37	36	43.4	44.7	ChronOS	Cervios

Abbreviations: CDA, cervical disc arthroplasty; ACDF, anterior cervical disectomy and fusion.

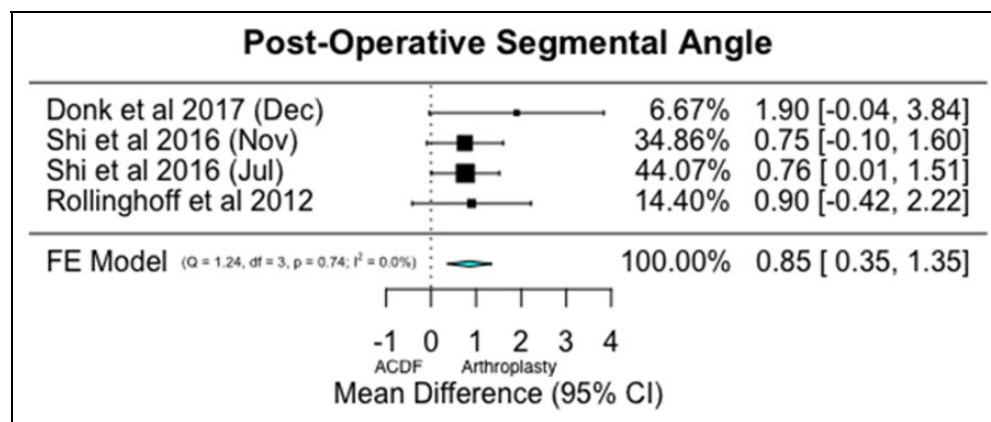


Figure 2. Segmental angle outcomes. Meta-analysis results of segmental angle outcomes illustrated in a forest plot. Meta-analysis revealed an increase in the segmental angle of stand-alone ACDF patients with a mean difference of 0.85° (95% CI = 0.35° to 1.35°), P = .0008).

were excluded for absent standard deviation values.^{33,34} VAS scores were reported on a scale of 0 to 10 in most studies, but in cases where VAS was reported at values 0 to 100, we converted the scores to a scale of 1 to 10. When considering VAS scores for arm pain, there was no statistically significant difference between the 2 treatments (mean difference 0.32

[95% CI = -1.09 to 1.73], P = .6558). Meta-analysis of VAS scores for neck pain indicated no statistically significant difference between the 2 treatments (mean difference 0.16 [95% CI = -0.99 to 1.31], P = .7867).

Japanese Orthopedic Association scores were also reported in 2 studies.^{26,28} There was no statistically significant

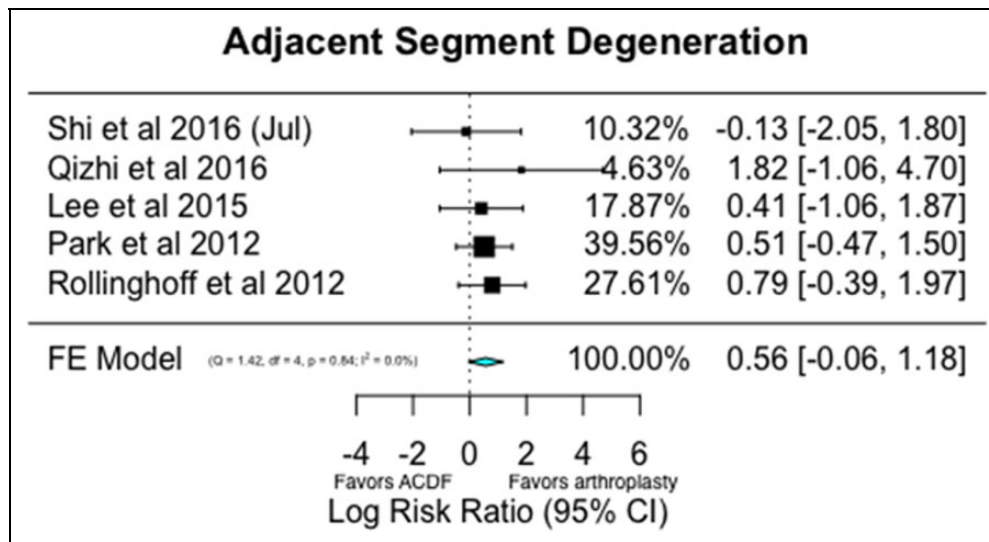


Figure 3. Adjacent segmental degeneration (ASD) outcomes. Meta-analysis results of ASD outcomes illustrated in a forest plot. Meta-analysis revealed a decreased risk of CDA patients developing ASD compared with patients undergoing stand-alone ACDF with a relative risk of 0.56 (95% CI = -0.06 to 1.18), $P = .0745$.

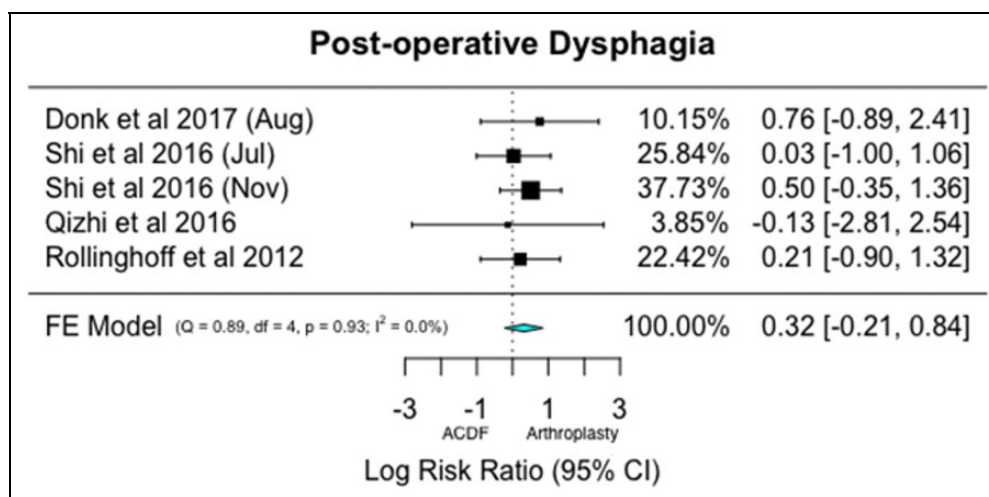


Figure 4. Dysphagia outcomes. Meta-analysis results of dysphagia outcomes illustrated in a forest plot. Meta-analysis revealed a decreased risk of CDA patients developing dysphagia compared with patients undergoing stand-alone ACDF, but this was not statistically significant. Relative risk = 0.32 (95% CI = -0.21 to 0.84), $P = .2368$.

difference between the 2 treatments (mean difference -0.05 [95% CI = -0.46 to 0.36], $P = .8040$).

Risk of Bias Across Studies

On visual inspection of the funnel plots, there was a possibility of publication bias found in the published studies measuring outcomes of blood loss, operative time, segmental angles, VAS arm, and VAS neck. These funnel plots indicated a possible deficit of studies with smaller sample sizes showing increased values for CDA. No other variables showed obvious asymmetry. Funnel plots for each variable are displayed in Supplement 2, available online.

Discussion

Stand-alone ACDF has been described to have reduced rates of ASD and dysphagia when compared with ACDF with anterior plating while also providing similar clinical outcomes for patients.³⁵⁻³⁹ However, it is not yet well understood if these rates of ASD, dysphagia, and clinical outcomes are comparable to CDA. This meta-analysis indicated that patients undergoing stand-alone ACDF have statistically significant increased postoperative segmental angles when compared to CDA, and it may potentially also have increased risk of developing ASD. Clinical outcome scores were similar between the 2 treatments when measuring NDI, VAS, and JOA scores.

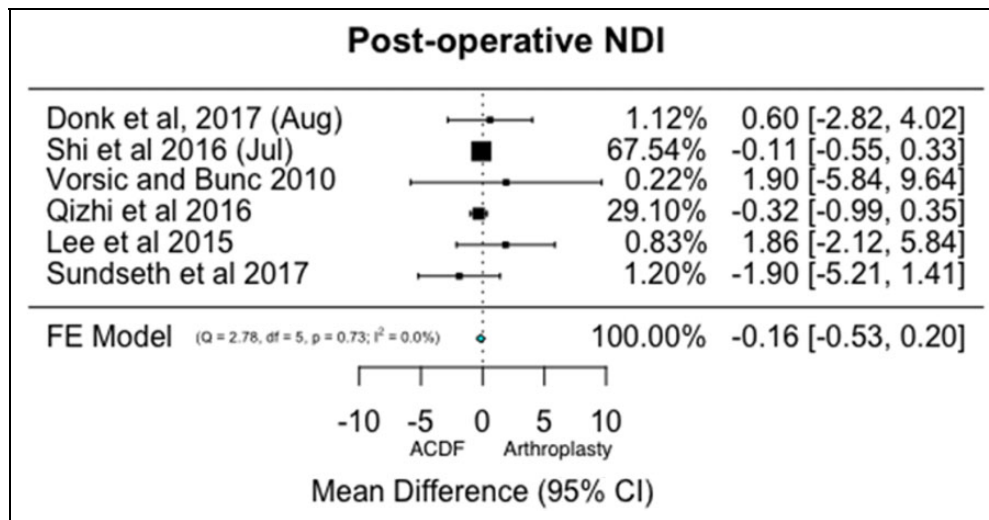


Figure 5. Neck Disability Index (NDI) score outcomes. Meta-analysis results of NDI score outcomes illustrated in a forest plot. Meta-analysis revealed similar NDI scores between patients treated with stand-alone ACDF and patients treated with CDA patients. Mean difference = -0.16 (95% CI = -0.53 to 0.20), $P = .3749$.

Summary of Evidence

Radiological Outcomes. A previous meta-analysis found that ACDF with anterior plating had increased segmental angles when compared with ACDF with stand-alone devices.⁴⁰ Our meta-analysis indicated that patients undergoing stand-alone ACDF have an increased postoperative segmental angle when compared with patients undergoing CDA. These findings suggest that stand-alone ACDF is superior to CDA for restoring cervical lordosis but may not be as effective at increasing the segmental angle as ACDF with anterior plate.

One indication for the use of ACDF, aside from correcting segmental instability, multilevel disc disease, facet arthropathy, ankylosis, and spine disease in patients with osteoporosis, is to correct an already collapsed disc space for the purpose of restoring disc height and enlarging the neuroforamina.⁴¹ The increased segmental angles found in our meta-analysis further support this indication in stand-alone devices. For CDA, patient selection criteria require the disease to be single-level, have a preserved range of motion, have normal sagittal alignment, and have an already normal disc space height with no osteoporosis or ankyloses.⁴¹ Thus, CDA is used in the preservation of disc height only, and a large change in segmental angle would not be expected. Additionally, treatment with CDA could potentially lead to kyphosis due to this negative effect on the cervical spine in patients whose lordotic angle is not adequate.

Complications. Since one main objective of performing CDA instead of ACDF is to reduce incidence of ASD, it is not surprising that this meta-analysis found decreased rates of ASD in CDA. Previous meta-analyses found increased rates of ASD in ACDF with anterior plating when compared with CDA.⁴²⁻⁴⁶

When considering how stand-alone ACDF compares to ACDF with anterior plate, early comparative studies have

reported largely decreased rates of ASD.³⁶⁻³⁹ The decreased ASD with stand-alone devices is likely explained by the less rigid fixation that occurs as a result of this procedure, in which the anterior plate is not fixated to the cervical vertebrae above and below the index level.

This meta-analysis indicated increased ASD in stand-alone ACDF when compared with CDA; however, this did not achieve statistical significance ($P = .0745$). Follow-up for the 5 studies included in this meta-analysis ranged from 17.5 to 44.6 months for stand-alone ACDF and 17.5 to 43.4 for CDA postoperatively. Timeframes of data collection for ASD outcomes is important to consider when comparing among studies, as ASD prevalence increases by longer lengths of follow-up. Of patients undergoing stand-alone ACDF, an average of 15% developed ASD. This is lower than the rates of ASD in ACDF with anterior plating reported in one meta-analysis with similar length of follow-up as the studies included in this meta-analysis.⁴⁴

Dysphagia is another common complication of fusion procedures, which is a result of esophageal retraction injury and injury to the recurrent laryngeal nerve during surgery.⁴⁷ Placement of an anterior plate further exacerbates this process, and dysphagia was found to be correlative with anterior plate thickness.⁴⁸ Previously published meta-analyses have found a statistically significant increase of dysphagia in patients who underwent ACDF with anterior plate compared with stand-alone ACDF.^{35,49} A large meta-analysis also showed that ACDF with anterior plating has higher rates of developing dysphagia when compared with CDA.¹² In this meta-analysis, which included a total of 527 patients in comparative studies measuring dysphagia, patients undergoing CDA had a lower risk ratio of developing dysphagia when compared with stand-alone ACDF but without statistical significance ($P = .2368$). Follow-up values ranged from <1 month to 107 months for both stand-alone ACDF and CDA, and the follow-up values

were largely similar to each other in each comparative study. This is important to consider, as incidence of dysphagia decreases by increasing length of follow-up.⁵⁰

Clinical Outcomes. Previous meta-analyses have found that clinical outcomes were similar to slightly favorable in CDA when compared with traditional ACDF.^{14,46,51} Additionally, ACDF is associated with increased rates of revision surgery on adjacent segments.⁵¹⁻⁵⁵ There is also a reduction in the range of motion for patients undergoing ACDF, and this degree of motion restriction is often a large factor in the decision-making process for patients.^{55,56}

When measuring outcomes of stand-alone ACDF compared with traditional ACDF, previous studies have validated the use of stand-alone ACDF techniques when assessing NDI, VAS, and JOA scores and rates of successful fusion.^{35,40,49,57} Of note, stand-alone devices were found to be an effective treatment option for patients with up to 3- and 4-level spine disease as well.^{57,58} However, one potential disadvantage of the stand-alone technique is an increased incidence of subsidence in the stand-alone device fusions when compared with traditional ACDF that is described in literature.⁵⁹⁻⁶¹

In this meta-analysis, NDI, VAS arm, VAS neck, and JOA scoring appeared the same between stand-alone ACDF and CDA, thus suggesting similar patient experience from the 2 treatments. Therefore, the benefit of CDA over stand-alone ACDF may not be as clear as opposed to CDA's advantage over the traditional ACDF in terms of clinical outcomes. The postoperative follow-up period for the 6 studies measuring NDI values ranged from 12 to 107 months for stand-alone ACDF and CDA. In the 2 studies measuring JOA values, follow-up ranged from 24 to 32 months for both procedures. Overall, in each individual comparative trial measuring clinical outcomes, lengths of follow-up were similar between the 2 treatment options. Similar length of follow-up is important as it may affect dysphagia rates, NDI, and JOA as well as ASD rates. It is also worthy to note that the majority of the studies included in this meta-analysis investigated single-level implantations of cervical disc prostheses. These single-level procedures are less likely to result in substantial differences in clinical outcomes such as NDI in comparison to multilevel procedures.

When making the decision to undergo stand-alone ACDF as opposed to CDA, patient selection criteria for procedures will continue to dictate which procedures are used, as some patients for stand-alone ACDF may not be eligible candidates to undergo CDA. Considerations for patient spinal mobility and range of motion postoperatively should also be included in clinical decision-making processes and in discussions with patients.

Blood Loss. Past literature is largely inconclusive when comparing CDA to traditional ACDF.^{14,39,51,62,63} When reviewing data comparing stand-alone ACDF to traditional ACDF, stand-alone fusion was found to have less blood loss.^{40,49} When comparing to CDA, this meta-analysis found that stand-alone ACDF has similar blood loss. This is understandable, since

both procedures use similar anterior approaches through the neck and do not require fixation of an anterior plate.

Operative Time. CDA is shown to have longer operative times than ACDF.^{51,64} This is reasonable, as the surgeon must ensure that the cervical device is placed at the midline of the vertebra and sitting in the middle of the disc space when placing the prosthesis. In fusions, the graft only needs to be inserted into the disc space. Performing fusions with stand-alone devices require decreased operative time when compared with traditional ACDF.^{35,40} This is also expected, as the surgeon does not spend time attaching an anterior plate to the adjacent vertebrae and to the intervertebral device in stand-alone fusions. There was a slightly decreased operative time in stand-alone ACDF compared with CDA with a mean difference of 2.94 minutes likely for a combination of these two reasons.

Limitations

This meta-analysis has several limitations. Patient profiles may differ for CDA and ACDF. This patient selection bias favored CDA, as this treatment modality is generally reserved for healthier and younger patients without significant spinal pathologies such as segmental instability, multilevel disc disease, and osteoporosis. Treatment with CDA is also contraindicated in patients with pregnancy, human immunodeficiency virus, and rheumatologic and other autoimmune disorders that could potentially be a confounder of clinical outcome scores.⁴¹

Only 12 studies were included in our analysis, as stand-alone ACDF is still a relatively new concept in spine disease treatment only recently gaining popularity in the past decade. In addition, no publication had all variables included in this meta-analysis, which further limited our sample size and statistical power for analysis. Each of the studies also had different lengths of follow-up time, and this limits the reliability and validity of variables measured. This is especially important when reviewing rates of ASD and dysphagia, where length of follow-up influences disease prevalence. One study measuring NDI scores included multilevel treatments,²⁷ and this was one factor we were unable to account for.

Similar to other clinical studies of spine surgery published in literature, the models of prostheses and stand-alone devices, if at all mentioned, were different in each study. This lack of standardization in devices is a potential confounder as different biomechanics and biokinematics may have affected outcome measures.

Additionally, there was no uniform homogeneity among disease severity, surgical procedure protocol, or facilities where the procedures were performed. As a result, funnel plots displaying data from studies measuring cervical angles, blood loss, operative time, VAS arm, VAS neck were asymmetric, indicating a possible publication bias. However, these may be false positive findings due to the small number of studies (2-5) included to study these parameters, which limits the power of funnel plots to accurately assess publication bias.^{65,66}

Conclusions

This meta-analysis indicates that stand-alone ACDF is equivalent to CDA when comparing clinical outcomes scores of patients postoperatively. Stand-alone ACDF was found to have statistically significant increased segmental angles when compared with CDA in addition to a potentially increased risk in development of ASD, though this difference did not achieve statistical significance. We suggest more comparative studies and randomized controlled trials be undertaken to compare rates of ASD and dysphagia between these 2 treatments options with the goal of establishing better treatment guidelines and describing optimal patient populations for these 2 different procedures.



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Supplemental Material

The supplemental material is available in the online version of the article.

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