**WEB APPENDIX:**

**Supplemental Table 1. Detailed Demographic and Results Table**

| **Study** | **Demographics and interventions** | **Inclusion/exclusion** | **Follow-up** | **Radiography** | **Adjacent segment (AS)** | **Cervical spine** |
| --- | --- | --- | --- | --- | --- | --- |
| **Range of motion (ROM)** | **Center of rotation (COR)** | **Alignment** | **Range of motion (ROM)** | **Alignment** |
| Anakwenze (2009)[2](#_ENREF_2)  | N = 180C-TDR (n = 89) (ProDisc-C) versus ACDF (n = 91) Sex: 49.4% male\*Age: mean 42.0 ± 7.7 years\* | Inclusion: All patients enrolled in a multicenter FDA IDE study with 1-level disease treated surgically at C3-C4, C4-C5, C5-C6, or C6-C7; age between 18 – 60 years; unresponsive to nonoperative care for 6 weeks or progressive signs/symtpoms of nerve root/spinal cord compression; NDI score ≥ 15/50 (30%); able to comply with study protocol.Exclusion: Cervical instability defined by translation on flexion-extension radiographs of ≥3 mm or ≥11° compared with adjacent level; fused adjacent level; radiographic evidence of facet arthrosis; known allergy to components; clinically compromised vertebral body at affected level due to current or past trauma; prior surgery at level to be treated; severe spondylosis (briding osteophytes, loss of disc height >50%, or absence of motion (<2°); neck or arm pain of unknown etiology; osteoporosis; Paget’s disease; severe diabetes mellitus; pregnant; active infection; steroids; autoimmune disease; or active malignancy. | f/u at 24 months f/u %: NR | * Neutral, flexion-extension radiographs
* Pre-operative, 1 and 3 months, and >2 years
* Quantitative Motion Analysis software was used to generate ROM at each level
* Outcomes
* Total post-operative sagittal alignment
* Total cervical ROM, ROM of superior and inferior segments
* Contributions of AS to whole neck motion
 | NR | NR | ***Sagittal alignment***† (change in ° from baseline = lordosis)* Cranial AS (24 mos.)
* C-TDR: 0.90 ± 2.69
* ACDF: 0.98 ± 2.80
* *P* = .26
* Caudal AS (24 mos.)
* C-TDR: -1.86 ± 2.36
* ACDF: -1.47 ± 2.86
* *P* = .05
* Index level (24 mos.)
* C-TDR: 2.96 ± 3.75
* ACDF: 4.21 ± 4.45
* *P* = .03
 | NR | ***Sagittal alignment*** (change in ° from baseline = lordosis)* C2 – C6 (24 mos.)
* C-TDR: 3.10 ± 8.11
* ACDF: 3.84 ± 8.38
* *P* = .49
 |
| Auerbach (2011)[4](#_ENREF_4) \*RCTLoE II | ProDisc-C (n = 103) versus ACDF (n = 106)Sex: 48.7% male\*Age: mean 42.0 ±7.7 years\* | See Anakwenze for details. | f/u at 24 months89.4% f/u | * Neutral lateral cervical spine radiographs
* Preoperative and 24 months
* C6 defined as distal endpoint for total cervical alignment (due to adequate visualization in all patients)
* Measurements performed independently using Quantitative Motion Analysis software to generate lordosis values at each level
* Outcomes:
* Sagittal alignment/lordosis of superior and inferior adjacent and operative discs
* Sagittal alignment/lordosis of overall cervical spine (C2-C6)
 | ***ROM*‡** (change in ° from baseline at 24 mos.)* 4th cranial AS
* C-TDR: 0.4 ± 3.9
* ACDF: 0.9 ± 4.0
* *P* = .03
* 3rd cranial AS
* C-TDR: 0.3 ± 5.4
* ACDF: 3.0 ± 5.9
* *P* = .05
* 2nd cranial AS
* C-TDR: 0.1 ± 5.1
* ACDF: 5.3 ± 6.8
* *P* = .05
* 1st cranial AS
* C-TDR: -1.0 ± 6.4
* ACDF: 3.3 ± 8.7
* *P* = .11
* Operative level
* C-TDR: -0.2 ± 9.4
* ACDF: -15.4 ± 8.4
* *P* < .001
* 1st caudal AS
* C-TDR: 0.6 ± 9.2
* ACDF: 5.9 ± 8.0
* *P* = .03

***Within group changes*** (from 0 to 24 months):* C-TDR: *P* = NS (all levels)
* ACDF: *P* = .001 (all but 4th cranial adjacent level)
 | NR | NR | ***Total Cervical ROM*‡** (change in ° from baseline at 24 mos.)* C2 – C7 (24 mos.)
* C-TDR: 5.9 ± 17.6
* ACDF: -0.8 ± 13.3
* *P* = .001
* Within group changes for C2 – C7 (from 0 to 24 mos.):
* C-TDR: *P* = .002
* ACDF: *P* = .56
 |  |
| Ahn (2009)[1](#_ENREF_1)Retro-spective Cohort Study | Pro-Disc C (n = 18) versus ACDF (n = 20)Sex: 63.2% maleAge: mean 41.5 years | InclusionDegenerative disc disease with radiculopathy or myelopathy, which had not responded to conservative treatment.ExclusionTrauma, preoperative radiographic instability, active infections, severe osteoporosis, inability (due to artifacts involving the shoulders) to visualize the affected disc space on optimized lateral fluoroscopy or severe kyphotic deformity, multiplce cervical lesions, or previous cervical surgery.  | f/u at mean 25 months% f/u NR | * Flexion-extension radiographs
* Preoperative and 24 months
* Measurements performed using Quantitative Motion Analysis software to generate range of motion (ROM) at each level
* Outcomes:
* Total cervical ROM from C2-C7
* Relative contribution to total cervical ROM from the operative, cranial and caudal adjacent segments
 | ***Superior AS ROM*** **§** (C4-C5)* Pro-Disc C
	+ Pre-Op: 9.7 ± 5.5
	+ 1 mos.: 7.1 ± 4.7
	+ 3 mos.: 9.1 ± 3.2
	+ Last f/u: 11.2 ± 3.5
* ACDF
	+ Pre-op: 9.7 ± 4.5
	+ 1 mos.: 11.6 ± 4.9
	+ 3 mos.: 12.5 ± 3.0
	+ Last f/u: 12.9 ± 3.9

***Inferior AS ROM***  (C6-C7)* Pro-Disc C
	+ Pre-Op: 9.1 ± 4.5
	+ 1 mos.: 6.1 ± 3.6
	+ 3 mos.: 8.4 ± 4.1
	+ Last f/u: 9.7 ± 4.3
* ACDF
	+ Pre-op: 8.1 ± 3.4
	+ 1 mos.: 9.7 ± 4.5
	+ 3 mos.: 10.1 ± 3.9
	+ Last f/u: 10.3 ± 4.1

***Inferior AS contribution to whole neck motion*** (% contribution, C4-C5/total ROM x 100)* Pro-Disc C
	+ Pre-Op: 20.4 ± 19.7
	+ 1 mos.: 20.0 ± 11.0
	+ 3 mos.: 21.4 ± 7.5
	+ Last f/u: 21.5 ± 5.9
* ACDF
	+ Pre-op: 22.9 ± 7.3
	+ 1 mos.: 33.4 ± 8.2
	+ 3 mos.: 31.1 ± 7.2
	+ Last f/u: 30.4 ± 5.8

***Superior AS contribution to whole next motion*** (% contribution, C6-C7/total ROM x 100)* Pro-Disc C
	+ Pre-Op: 19.2 ± 9.6
	+ 1 mos.: 16.7 ± 9.5
	+ 3 mos.: 19.7 ± 12.8
	+ Last f/u: 18.6 ± 7.8
* ACDF
	+ Pre-op: 19.1 ± 9.0
	+ 1 mos.: 28.0 ± 8.3
	+ 3 mos.: 25.1 ± 8.2
	+ Last f/u: 24.2 ± 7.5
 | NR | NR | ***Total Cervical ROM*** (C2-C7)* Pro-Disc C
	+ Pre-Op: 47.5 ± 16.5
	+ 1 mos.: 36.0 ± 15.4
	+ 3 mos.: 42.6 ± 41.8
	+ Last f/u: 52.1 ± 12.2
* ACDF
	+ Pre-op: 42.3 ± 12.3
	+ 1 mos.: 34.7 ± 11.9
	+ 3 mos.: 40.2 ± 10.6
	+ Last f/u: 42.5 ± 9.8
 | **Sagittal Alignment**  (Measure-ment of Cobb angles for whole of cervical spine)* Pro-Disc C
	+ Pre-Op: -6.6 ± 8.1
	+ 1 mos.: -8.2 ± 8.4
	+ 3 mos.: -10.2 ± 9.4
	+ Last f/u: -11.5 ± 8.9
* ACDF
	+ Pre-op: -10.7 ± 8.1
	+ 1 mos.: -13.2 ± 11.0
	+ 3 mos.: -14.0 ± 9.1
	+ Last f/u: -14.2 ± 8.8
 |
| Kim (2009)[11](#_ENREF_11)Pro-spective Cohort Study | Bryan artificial disc ( n = 51) versus ACDF (n = 40)Sex: 61.2% maleAge: mean 45.2 years | InclusionPatients with symptomatic single or two-level cervical disc disease receiving treatment via either Bryan Cervical Artifical Disc Prothesis or ACDF with autogenous bone. ExclusionNR | f/u at mean 18-20 months% f/u NR | * Neutral, flexion-extension radiographs
* Pre-operative, post-operative and follow-up
* Measurements on digital radiographs were made using Infinitt PiviewSTAR 5051 software.
* Outcomes
* Total post-operative sagittal alignment
* ROM of superior and inferior segments at the single and double level
 | ***Sagittal AS ROM***  (degrees)Single level C-TDR* Upper level
	+ Pre-op: 8.7 ± 2.1
	+ Post-op: 9.1 ± 2.0
	+ F/u: 9.5 ± 2.1
* Lower level
	+ Pre-op: 8.3 ± 2.3
	+ Post-op: 8.7 ± 2.3
	+ F/u: 9.2 ± 2.4

Single level ACDF* Upper level
	+ Pre-op: 9.4 ± 1.3
	+ Post-op: 10.1 ± 1.7
	+ F/u: 10.2 ± 1.4
* Lower level
	+ Pre-op: 11.4 ± 2.3
	+ Post-op: 9.0 ± 2.5
	+ F/u: 10.8 ± 3.4

*p <* .0005Double level C-TDR* Upper level
	+ Pre-op: 9.0 ± 1.6
	+ Post-op: 9.0 ± 2.0
	+ F/u: 9.9 ± 1.8
* Lower level
	+ Pre-op: 8.5 ± 1.9
	+ Post-op: 9.0 ± 2.0
	+ F/u: 9.4 ± 2.1

Double level ACDF* Upper level:
	+ Pre-op: 7.7 ± 1.1
	+ Post-op: 2.8 ± 0.7
	+ F/u: 4.3 ± 0.9
* Lower level
	+ Pre-op: 5.5 ± 1.7
	+ Post-op: 4.5 ± 1.5
	+ F/u: 6.2 ± 1.5

*p <* .0001 | NR | NR | NR**See note in next column.** | NR**NOTE.** The following data were reported for sagittal alignment, but the methods by which these were described are more in line with ROM. As we cannot be certain which outcome was reported, this data was not included in our results.***Overall sagittal alignment*** (degrees) (C2-C7)Single level C-TDR* + Pre-op: 49.5 ± 6.4
	+ Post-op: 51.4 ± 6.5
	+ F/u: 53.2 ± 5.8

Single level ACDF* + Pre-op: 51.4 ± 7.3
	+ Post-op: 32.2 ± 3.2
	+ F/u: 39.6 ± 5.6

Double level C-TDR* + Pre-op: 51.4 ± 6.6
	+ Post-op: 53.5 ± 6.7
	+ F/u: 55.7 ± 6.0

Double level ACDF* + Pre-op: 43.9 ± 9.5
	+ Post-op: 30.3 ± 6.6
	+ F/u: 35.0 ± 2.3

*p <* .0001 |
| Nabhan (2011)[12](#_ENREF_12)RCT | ProDisc-C (n = 10) versus ACDF (n = 10) Sex: 65% maleAge: mean 43 ± 9 years | InclusionSymptomatic degenerative disc disease with single level radiculopathy, not responding to a trial of conservative treatmentExclusionNR | f/u at 1 week, 6 and 12 months100% f/u | * Neutral position and extension with head rotated to the right
* 1, 3, 6, 12, and 24 weeks
* UmRSA software to generate ROM at each level
* Outcomes
* Post-operative ROM in the treated and cranial adjacent levels
* Post-operative right-sided rotation and bending in treated and cranial adjacent levels
 | ***Extension*** (° at f/u)* Cranial AS (12 mos.)
* C-TDR: 14.5 ± 2.1
* ACDF: 18.1 ± 3.1
* *P* = .05
* Index level (12 mos.)
* C-TDR: 2.08 ± 1.13
* ACDF: 0.81 ± 0.26
* *P* = .02

***Right-sided rotation*** (°at f/u)* Caudal AS (12 mos.)
* C-TDR: 13.3 ± 2.3
* ACDF: 16.4 ± 2.9
* *P* = .05
* Index level (12 mos.)
* C-TDR: 3.07 ± 1.38
* ACDF: 0.62 ± 0.3
* *P* = .013

***Right-sided bending*** (°at f/u)* Caudal AS (12 mos.)
* C-TDR: 8.8 ± 2.0
* ACDF: 10.1 ± 2.7
* *P* = .05
* Index level (12 mos.)
* C-TDR: 0.9 ± 0.5
* ACDF: 0.56 ± 0.28

*P* = .06 | NR | NR | NR | NR |
| Park (2008)[15](#_ENREF_15)Retro-spective Cohort Study | Arthroplasty (n = 21) versus ACDF (n = 32)Sex: 58.5% maleAge: mean 46.2 years | InclusionCervical soft disc herniation, presenting with upper extremity radiculopathy, with or without axial neck pain.ExclusionMulti-level disc disease, evidence of cervical instability, severe degeneration as seen by radiography, serious medical problems, and revision surgery.  | f/u at 1.5, 3, 6, and 12 months% f/u NR | * Neutral, flexion-extension radiographs
* Cervical lordosis was measured as angle formed by lines drawn parallel to caudal endplace of C-2 and C-7
* Segmental ROM was defined as difference in segmental lordosis between flexion and extension, adjacent segmental ROM was measured in the same way.
* Technique used to measure radiographs: NR
* Outcomes
* Post-operative ROM of superior and inferior segments
* Total cervical lordosis
 | ***Upper Segment ROM**** Pre-op
	+ Arthroplasty: 14.43
	+ ACDF: 10.63
* Post-op
	+ Arthroplasty: 12.58
	+ ACDF: 11.66

*p* = .570***Lower Segment ROM**** Pre-op
	+ Arthroplasty: 11.34
	+ ACDF: 10.21
* Post-op
	+ Arthroplasty: 11.64
	+ ACDF: 11.26

*p =* .7555 | NR | NR | NR | ***Cervical Lordosis*** (C2-C7)* Arthroplasty
	+ Pre-op: 29.79
	+ 1.5 mos.: 34.75
	+ 3 mos.: 30.47
	+ 6 mos.: 28.59
* ACDF
	+ Pre-op: 24.27
	+ 1.5 mos.: 19.33
	+ 3 mos.: 17.48
	+ 6 mos.: 17.69
 |
| Park (2011)[14](#_ENREF_14)RCT | PCM artificial cervical disc (n = 272) versus ACDF (n = 182) Sex: % male NRAge: mean 44.6 years | InclusionPatients undergoing either C-TDR or ACDF for the treatment of cervical radiculopathy or myelopathy in an IDE clinical evaluation of PCM artificial disc implants.ExclusionPrevious adjacent level fusions | f/u at 1 week, 6 and 12 months% f/u NR | * Neutral, flexion-extension radiographs
* Preoperative, 6 weeks, and 3, 6, 12, 18, and 24 months.
* Measurements performed using Quantitative Motion Analysis software to generate range of motion (ROM) at each level
* Outcomes
* Post-operative sagittal rotation, translation, horizontal and vertical COR
* Disc angle in the index, cranial adjacent, and caudal adjacent levels
 | ***ROM*** (change in ° from baseline, all 95% CI and *P* values NR)* Cranial AS (12 mos.)
* C-TDR: 1.0
* ACDF: 1.4
* Caudal AS (12 mos.)
* C-TDR: 0.7
* ACDF: 0.9
* Index level (12 mos.)
* C-TDR: -1.8
* ACDF: -6.8

***Translation*** (change in mm from baseline, all 95% CI and *P* values NR)* Cranial AS (12 mos.)
* C-TDR: 0.1
* ACDF: 0.2
* Caudal AS (12 mos.)
* C-TDR: 0.1
* ACDF: 0.2
* Index level (12 mos.)
* C-TDR: 0.2
* ACDF: -0.8
 | ***Horizontal COR (COR-X)*** (change in mm from baseline, all 95% CI and *P* values NR)* Cranial AS (12 mos.)
* C-TDR: -0.1
* ACDF: -1.4
* Caudal AS (12 mos.)
* C-TDR: 0.0
* ACDF: 0.1
* Index level (12 mos.)
* C-TDR: 1.0
* ACDF: NR

***Vertical COR (COR-Y)*** (change in mm from baseline, all 95% CI and *P* values NR)* Cranial AS (12 mos.)
* C-TDR: 0.2
* ACDF: 0.1
* Caudal AS (12 mos.)
* C-TDR: 0.4
* ACDF: 0.3
* Index level (12 mos.)
* C-TDR: 1.5
* ACDF: NR
 | ***Lordosis (“disc angle”)*** (change in ° from baseline, all 95% CI and *P* values NR)* Cranial AS (12 mos.)
* C-TDR: 0.8
* ACDF: -0.1
* Caudal AS (12 mos.)
* C-TDR: -1.1
* ACDF: -2.3
 | NR | NR |
| Peng-Fei (2008)[16](#_ENREF_16)RCT | N = 24Arthroplasty (n = NR) versus ACDF (n = NR)Sex: 70.8% maleAge: mean 42 years | InclusionIntervertebral disc hernia (C5/C6)ExclusionNR | f/u at 1 week, 3, 6, and 12 months 100% f/u  | * Dynamic lateral position X-ray was used to determine ROM
* Pre-op, 1 week, 3, 6, and 12 months.
* Technique used to measure radiographs: NR
* Outcomes
* Post-operative ROM of adjacent intervertebral space
 | * Intervertebral AS
* ACDF (before): 11.9° ± 5.8°
* ACDF (after): 11.4° ± 4.9°
* C-TDR (before): 12.8° ± 5.7°
* C-TDR (after): 11.2° ± 3.9
 | NR | NR | NR | NR |
| Powell (2010)[17](#_ENREF_17)RCTSingle-site report of multi-center IDE trial; same set of patients as reported on in Sasso 2011. Include as different outcomes were reported. | Bryan Cervical disc (n = 22) versus ACDF (n = 26)Sex: 65% maleAge: Mean 41.8 years | InclusionSkeletally mature patients undergoing primary surgery for the treatment of mechanically stable cervical radiculopathy between C3-4 and C6-7, which had not responded to 6 weeks nonoperative treatment. ExclusionInstability, facet arthrosis, radiculopathy or myelopathy at multiple levels, and previous cervical spine surgery.  | f/u at , 6, 12, and 24 months100% f/u | * Lateral neutral, flexion-extension radiographs
* Pre-operatively, 3 months, and 24 months
* Quantitative Motion Analysis software was used to generate ROM at each level
* Outcomes
* Post-operative ROM at superior segments
* Translation at superior segments
 | ***Sagittal ROM*** (Change in intervertebral rotation (degrees)* Cephalad level, C-TDR vs. ACDF:
* Preop: 8.46 vs. 9.58
* 12 mos.: 12.8 vs. 11.91
* 24 mos.: 12.39 vs. 13.17
* *P* = NS
* Caudal level, C-TDR vs. ACDF:
* Preop: 6.42 vs. 8.44
* 12 mos.: 12.64 vs. 9.38
* 24 mos.: 13.92 vs. 11.44
* *P* = NR

***Translation*** (Percentage of endplate width)* Level above target disc, C-TDR vs. ACDF:
* Pre-op: ~8.1 vs. ~8.1
* 3 mos.: ~7.9 vs. ~8.0
* 6 mos.: ~8.1 vs. ~12.2
* 12 mos.: ~8.1 vs. ~11.0
* 24 mos.: ~7.9 vs. ~10.2
* Level below target disc, C-TDR vs. ACDF:
* Pre-op: ~3.5 vs. ~6.2
* 3 mos.: ~7.0 vs. ~9.8
* 6 mos.: ~7.2 vs. ~15.0
* 12 mos.: ~6.0 vs. ~9.0
* 24 mos.: ~6.2 vs. ~1.8
 | ***COR X*** (mm)* C-TDR (Index vs. Above vs. Below)
* Pre-op: -1.18 vs. -1.35 vs. -2.6
* 12 mos.: -1.43 vs. -1.16 vs. -2.74
* 24 mos.: -1.46 vs. -0.99 vs. -2.08
* ACDF (Index vs. above vs. below)
* Pre-op: -1.20 vs. -2.44 vs. -2.75
* 12 mos.: -0.94 vs. -2.78 vs. -2.21
* 24 mos.: -0.89 vs. -2.58 vs. -3.21

***COR Y*** (mm)* C-TDR (Index vs. above vs. below)
* Pre-op: -7.8 vs. -8.07 vs. -12.96
* 12 mos.: -12.72 vs. -7.68 vs. -14.53
* 24 mos.: -12.03 vs. -7.80 vs. -13.17
* ACDF
* Pre-op: -9.23 vs. -9.43 vs. -12.56
* 12 mos.: -13.14 vs. -8.72 vs. -9.91

24 mos.: -15.91 vs. -8.64 vs. -13.38 | NR | NR | NR |
| Rabin (2007)[18](#_ENREF_18)Retro-spective case-control Study | Bryan Cervical disc (n = 10) versus ACDF (n = 10)Sex: 80% maleAge: mean 43.2 years | InclusionSingle level disc disease at the surgical levelExclusionRadiographic or clinical evidence of additional diseased spinal segments. | F/u at 24 months% f/u NR | * Lateral upright and lateral flexion/extension radiography
* Preoperatively, 6 weeks, 3, 6, 12, and 24 months
* Quantitative Motion Analysis software was used to generate ROM at each level
* Outcomes
	+ Overall (C2-C7) sagittal alignment and lordosis
 | ***Superior segment ROM*** (C-TDR vs. ACDF) (°)* Pre-op: ~10.8 vs. ~10.8
* 24 mos: ~14.8 vs. ~ 12.0
* *P* = NS

***Superior segment translation*** (C-TDR vs. ACDF p-values)* Pre-op: 0.73
* 24 mos: 0.23
 | NR | NR | NR | NR |
| Sasso (2011)[21](#_ENREF_21)RCTSingle-site report of multi-center IDE trial. Same set of patients as Powell 2010. Include as different outcomes were reported. | Bryan cervical disc (n = 22) versus ACDF (n = 26)Age: NRSex: NR | InclusionSymptomatic cervical radiculopathy, or myelopathy refractory to nonoperative interventionsExculsionNR | f/u at 6 weeks, 3, 6, 12, and 24 months% f/u NR | * Neutral, flexion-extension radiographs
* Pre-operative, 3, 6, 12, and 24 months
* Quantitative Motion Analysis software was used to generate ROM at each level
* Outcomes
* Post-operative sagittal motion
* Translation of levels above and below target disc
* Horizontal and vertical COR.
 | NR | NR | NR | NR | ***Sagittal Lordosis*** (Average C2-C7 angles, in degrees)* C-TDR
* Pre-op: 0.7
* Post-op: 3.2
* 3 mos.: 3.0
* 6 mos.: 4.9
* 12 mos.: 6.9
* 24 mos.: 4.4
* ACDF
* Pre-op: 0.5
* Post-op: 10.3
* 3 mos.: 6.0
* 6 mos.: 5.7
* 12 mos.: 3.4
* 24 mos.: 5.8
 |
| Yi (2009)[24](#_ENREF_24)Retro-spective Cohort Study | Bryan Cervical disc (n = 15) versus ACDF (n = 13)Sex: 53.6% maleAge: mean 46.5 years | InclusionUnilateral cervical radiculopathy caused by herniated disc.ExclusionSigns of myelopathy or additional degenerative changes on plain radiography | f/u :C-TDR: 23.0 mosACDF: 13.8 mos.% f/u NR | * Static neutral lateral radiographs, and dynamic cervical spine radiographs
* Pre-operatively and post-operatively
* Quantitative Motion Analysis software was used to measure angles at each level
* Outcomes
* Total post-operative sagittal alignment and ROM
* ROM of adjacent segments
 | ***AS ROM***  (degrees)* C-TDR
	+ Pre-op: 13.8 ± 3.9
	+ Post-op: 14.1 ± 3.4
* ACDF
	+ Pre-op: 10.4 ± 6.4
	+ Post-op: 12.1 ± 4.5
 | NR | NR | ***Cervical ROM*** (degrees)(C2-C7)* C-TDR
	+ Pre-op: 56.5 ± 16.1
	+ Post-op: 57.0 ± 17.2
* ACDF
	+ Pre-op: 42.0 ± 19.8
	+ Post-op: 42.3 ± 8.8
 | ***Sagittal Alignment*** (Degrees)(C2-C7)* C-TDR
	+ Pre-op: -20.0 ± 7.9
	+ Post-op: -14.4 ± 12.3
* ACDF
	+ Pre-op: -9.4 ± 13.4
	+ Post-op: -15.5 ± 7.6
 |

ACDF: anterior discectomy and fusion; AS: adjacent segment; CI: Confidence Interval; COR: center of rotation; C-TDR: cervical total disc replacement; f/u: follow-up; LoE: level of evidence; NR: not reported; ROM: range of motion

\* After loss to follow-up

† Sagittal alignment data was taken from the text and is different than that reported in study table [Anakwenze 2009].

**‡** Segmental Contribution to Total Cervical ROM defined as ratio of segmental ROM to total cervical ROM from C2 – C7; first inferior values for subjects with C5-C6 or superior operative level [Auerbach 2011].

LoE Level of evidence, NR not reported, COR center of rotation, ROM range of motion, TDR total disc replacement, ACDF anterior cervical discectomy and fusion, f/u follow-up.

**Supplemental text: details of and results from individual studies**

***Summary of the literature available***

Five RCTs[1-5](#_ENREF_1) reported on three multicenter Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trials designed to compare single-level cervical arthroplasty and ACDF. All were moderate quality RCTs. Measurements were performed independently in each study using Quantitative Motion Analysis software.

Auerbach et al evaluated the ProDisc-C (Synthes Spine, West Chester, PA) (n = 93) to ACDF (n = 94)[2](#_ENREF_2). Patient diagnosis was single-level symptomatic cervical disc disease with radiculopathy and/or myelopathy. For inclusion, patients must have demonstrated no improvement following at least six weeks of nonoperative care or progressive signs/symptoms of nerve root or spinal cord compression, a Neck Disability Index (NDI) score of at least 15/50, and age between 18 and 60 years. Exclusion criteria were extensive (see Supplementary Table 1) and included cervical instability, fused adjacent level, facet arthrosis, prior surgery at the index level, severe spondylolosis, and osteoporosis (among others). Patients were followed for 24 months, with complete follow-up available for 89.4% of patients. Auerbach et al reported adjacent segment and global cervical range of motion as measured on flexion-extension. Anakwenze et al reported adjacent segment and global cervical sagittal alignment outcomes on the same set of patients[1](#_ENREF_1).

Park et al evaluated the porous coated motion (PCM) artificial disc (NuVasive, La Jolla, CA) (n = 272) in comparison to ACDF (n = 182)[3](#_ENREF_3). Similar to Auerbach et al, Park et al (2011) included patients with single-level radiculopathy or myelopathy, and excluded those who had undergone prior adjacent level fusions[3](#_ENREF_3). All enrolled patients were followed for 12 months. ROM was measured on flexion-extension radiographs. Outcomes reported include adjacent segment range of motion (flexion-extension and translation), center of rotation, and sagittal alignment.

Two studies reported outcomes from patients at a single site of a multicenter IDE trial[4](#_ENREF_4),[5](#_ENREF_5). Patients with single-level cervical radiculopathy who had not responded to nonoperative therapy of at least six weeks’ duration were randomized to receive the Bryan Cervical disc (Medtronic Sofamor Danek, Inc., Memphis, Tennessee) (n = 22) or ACDF (n = 26). Patients with instability, facet arthrosis, radiculopathy or myelopathy at more than one level, or a history of cervical surgery were excluded. Patients were followed for 24 months; the percentage of patients with complete follow-up was not reported. Powell et al reported adjacent segment range of motion (translation) and center of rotation[4](#_ENREF_4); Sasso et al evaluated global cervical sagittal alignment[5](#_ENREF_5).

Two additional small RCTs met our inclusion criteria. Nabhan et al conducted a small randomized controlled study in which patients with single-level degenerative disc disease and radiculopathy were randomized to receive arthroplasty (ProDisc-C) (n = 10) or ACDF (n = 10)[6](#_ENREF_6). Patients were followed for 12 months; complete follow-up was available for all patients. This was a moderate to poor quality RCT; independent or blind assessment of radiographs was not reported. Range of motion (extension) was reported. The study utilized RSA, which is a highly accurate in vivo means to measure motion; however, the technique used only allowed measurement from neutral to full extension.

Peng-Fei et al conducted an RCT in which 24 patients with disc herniation at C5-C6 were randomized to undergo either arthroplasty (device not specified) or ACDF [7](#_ENREF_7). Complete follow-up to 12 months was available for 100% of patients. This was a moderate to poor quality RCT; no mention was made as to whether radiographs were evaluated in an independent manner or the method by which measurements were taken. This study reported adjacent segment range of motion.

In a prospective cohort study, Kim et al treated patients with symptomatic 1- or 2-level cervical disc disease with either the Bryan artificial disc (n = 51) or ACDF (n = 40)[8](#_ENREF_8); outcomes were reported separately for 1- versus 2-level patients. Single-level patients were followed for a mean of 18 (range, 12 to 40) months, while 2-level patients were followed for a mean of 20 (range, 13 to 38) months. The percentage of patients with complete follow-up was available was not clearly reported. This study was of moderate to poor quality, and did not report whether radiographs were evaluated in an independent manner. Measurements were made using Infinitt PiviewSTAR 5051 software. Outcomes reported included adjacent segment range of motion and global cervical alignment.

All four of the retrospective cohort studies evaluated outcomes in patients with single-level disc disease[9-12](#_ENREF_9).

Ahn et al conducted a retrospective cohort study in which patients with degenerative disc disease and either radiculopathy or myelopathy and had not responded to six weeks of conservative care underwent either arthroplasty (ProDisc-C) (n = 18) or ACDF (n = 20)[9](#_ENREF_9). Exclusion criteria were extensive (see Supplementary Table 1), and included a history of cervical spinal surgery. Patients were followed for a mean of 25 (range, 24 to 32) months; complete follow-up was available for all patients. This was a moderate quality cohort study; radiographic outcomes were analyzed in an independent manner using Quantitative Motion Analysis software. Outcomes included adjacent segment and global cervical range of motion, as well as global cervical sagittal alignment.

Park et al (2008) compared outcomes following primary arthroplasty using the Mobi-C (LDR Medical, Troyes Fr) (n = 21) or ACDF (n = 32) in a retrospective cohort study of patients with cervical disc herniation and radiculopathy[10](#_ENREF_10). Patients were followed for 12 months; the percentage of patients with complete follow-up available was not reported. The authors reported adjacent segment range of motion, center of rotation, and sagittal alignment.

Rabin et al reported outcomes from a retrospective case-control study in which patients with single-level cervical disc disease underwent arthroplasty with the Bryan Cervical disc (n = 10) or ACDF (n = 10)[11](#_ENREF_11). Mean patient age was 43 years, and 80% of patients were male. Patients were followed for 24 months, and the percentage of patients with complete follow-up was not reported. This study reported range of motion (flexion-extension and translation) at the adjacent segment.

Yi et al conducted a retrospective cohort study of patients with single-level cervical radiculopathy resulting from disc herniation treated with arthroplasty (Bryan cervical disc) (n = 15) or ACDF (n = 13)[12](#_ENREF_12). Patients with myelopathy were excluded. Patients had a mean age of 47 years, and 54% of patients were male. Results were reported at last follow-up, but length of follow-up was longer in the arthroplasty group (23.0 months) than in the ACDF group (13.8 months). The percent of patients with complete follow-up was not reported. Outcomes of interest included adjacent segment range of motion as well as global cervical range of motion and sagittal alignment.

The retrospective studies by Park (2008), Rabin, and Yi were of poor quality[10-12](#_ENREF_10). No information was reported regarding blinding or use of independent assessors; measurements were taken using Quantitative Motion Analysis software.

**Results from individual studies**

**Adjacent segment angular ROM**

***Cranial adjacent segment angular motion (Supplemental Table 2)***

All four RCTs reported on range of motion at the cranial adjacent segment. Park et al (2011) reported a similar increase in angular ROM in both the arthroplasty and fusion treatment groups at 12 months compared with baseline (1.0° versus 1.4°, respectively; p-value not reported). Baseline and 12 month values were similar between treatment groups, although the authors reported that the within-group changes in the ACDF group had a statistically meaningful increase in range of motion at the cranial adjacent segment at 12 months compared to preoperative values (*P* = .003) but no suchdifference was found in the arthroplasty group (*P* = .43)[3](#_ENREF_3). Auerbach et al found that the change in cranial adjacent segment ROM at 24 months from baseline was similar in both the arthroplasty and fusion groups (-1.0 ± 6.4° versus 3.3 ± 8.7°), respectively.The changes in range of motion at the cranial adjacent segment were not statistically meaningful in the arthroplasty group; however, as -Park et al (2011) did, Auerbach reported that the ACDF group saw a significant increase in range of motion at 24 months compared with baseline values (*P* < .001)[2](#_ENREF_2). Powell et al reported that both the arthroplasty and fusion groups had a similar increase in ROM at 24 months compared with baseline (3.9° versus 3.6°, respectively; p-value not reported). Range of motion significantly increased within both treatment groups (*P* = .006 (arthroplasty); *P* = .044 (ACDF))[4](#_ENREF_4). Finally, Nabhan et al reported that the cranial adjacent segment motion from neutral to extension after surgery was similar in both the arthroplasty and ACDF groups at one week (15.5° versus 15.95°, respectively; *P* > .05) and twelve months (14.5° versus 18.1°, respectively; *P* > .05) following surgery[6](#_ENREF_6). Baseline ROM values were not included, thus the change in ROM could not be reported.

Cranial adjacent segment range of motion was also reported by all four cohort studies. Park et al (2008) reported a small decrease in ROM in the arthroplasty group and a small increase in the fusion group at 6 to 12 months compared with baseline values (-1.8° versus 1.1°, respectively; p-value not reported). This result may be due to the difference in preoperative ROM values between the treatment groups (14.4° versus 10.6°, respectively; *P*-value not reported), which, at 6 to 12 months follow-up, converged toward the mean in both treatment groups (12.6° versus 11.7°, respectively; *P* = .570)[10](#_ENREF_10). Rabin et al found that ROM at the cranial adjacent segment increased in both the arthroplasty and ACDF treatment groups at 24 months from preoperative values (4.0° versus 1.2°, respectively; p-value not reported). Ahn et al reported similarly increased ROM values at a mean of 25 months follow-up in both the arthroplasty and ACDF groups (1.5° versus 3.2°, respectively; *P*-value not reported) compared with preoperative ROMs. The authors noted that the within-group increase in range of motion from baseline values was statistically meaningful in the ACDF (*P* < .05) but not the ProDisc-C group[9](#_ENREF_9). Kim et al found that in single-level arthroplasty and ACDF procedures, range of motion at the cranial adjacent segment had increased slightly at final follow-up in both treatment groups from preoperative values (0.8° versus 0.8°, respectively; *P* = .29). In contrast, while patients undergoing two-level arthroplasty had a ROM that remained more or less the same, those undergoing two-level ACDF demonstrated a substantial decrease in ROM at the cranial adjacent segment compared with baseline values (0.1° versus -3.4°, respectively; *P* < .0001))[8](#_ENREF_8).

***Caudal adjacent segment angular motion (Supplemental Table 2)***

At the caudal adjacent segment, range of motion was reported by three of the four RCTs. Park et al (2011) found that baseline range of motion was similar between the arthroplasty and ACDF groups at baseline as well as at twelve months. Thus, both groups saw a slight increase in ROM at the caudal adjacent segment (0.7° versus 0.9°, respectively; p-value not reported). Furthermore, within-group changes between baseline and twelve months were not statistically meaningful in either treatment group[3](#_ENREF_3). Powell et al reported on range of motion at the caudal adjacent segment following Bryan cervical disc arthroplasty versus ACDF preoperatively (6.4° versus 8.4°, respectively) and at 24 months (13.9° versus 11.4°, respectively)[4](#_ENREF_4). The change in ROM from baseline was higher in the arthroplasty group (7.5° versus 3.0°, respectively), however the authors made no comment on these results. It is not clear whether the differences between the ROM values between the groups at baseline affected these results. In contrast, Auerbach reported the change in range of motion from baseline was statistically greater in the fusion group compared with the arthroplasty group (0.6 ± 9.2° versus 5.9 ± 8.0°, respectively; *P* = .03). Further, while the changes in ROM at the caudal adjacent segment were not statistically significant in the arthroplasty group (*P* = .63), there was a statistically meaningful increase in range of motion at 24 months compared with baseline values in the fusion group (*P* < .001)[2](#_ENREF_2). Together, these three RCTs provide inconsistent results: one RCT reporting a modest increase in ROM at the caudal adjacent segment that was similar in both treatment groups[3](#_ENREF_3); another reporting significantly higher ROM in the arthroplasty group[2](#_ENREF_2); and another reporting higher ROM in the ACDF group[4](#_ENREF_4).

**Global cervical spine (C2-C7) angular range of motion *(Supplemental Table 3)***

One RCT[2](#_ENREF_2) and two retrospective cohort studies reported global range of motion for the cervical spine between C2 and C7. Auerbach et al reported a significantly greater change in global cervical range of motion in the arthroplasty group compared with the ACDF group between baseline and 24 months (5.9 ± 17.6° versus -0.8 ± 13.3°, respectively; *P* = .001). Ahn et al also found that the change in cervical range of motion was higher following arthroplasty compared with baseline values (4.6° versus 0.2°, respectively) but according to our analysis the difference was not statistically significant.The within-group differences between preoperative and final follow-up cervical range of motion values were not statistically meaningful in either treatment group (*P* ≥ .05)[9](#_ENREF_9). In contrast, Yi et al reported similar change in cervical range of motion from baseline to a mean of 19 months in the arthroplasty and ACDF groups prior to surgery (0.5° versus 0.3°, respectively; *P*-value not reported). There were no statistically meaningful within-group changes between baseline and final follow-up for either treatment group (*P* ≥.16)[12](#_ENREF_12).

**Adjacent segment sagittal alignment/lordosis**

***Cranial adjacent segment alignment (Supplemental Table 5)***

At the cranial adjacent level, Park et al reported that the disc angles were similar in both the arthroplasty and ACDF treatment groups at baseline and at 12 months, with no clinically meaningful difference between treatment groups in the change from baseline (0.8° versus -0.1°, respectively; p-values not reported). Further, disc angles did not change significantly from baseline values in either treatment group (*P* > .2)[3](#_ENREF_3). Anakwenze et al found that at the cranial adjacent segment, lordosis did not change significantly in either the arthroplasty or ACDF treatment groups between baseline and 24 months (1.0 ± 2.8° versus 0.9 ± 2.7°, respectively; *P =* .26). Both treatments yielded statistically significant within-group increases in lordosis at the cranial adjacent level (*P* ≤ .006 for each).

***Caudal adjacent segment alignment (Supplemental Table 5)***

At the caudal level, Park et al found that while preoperative disc angles were similar in both the arthroplasty and fusion groups (4.3 ± 3.8° versus 5.0 ± 3.8°), respectively, by 12 months, the disc angle in the ACDF group (but not the arthroplasty group) had become significantly less lordotic (*P* < .001) (arthroplasty: 3.2 ± 4.1° versus 2.7 ± 4.2°). The change in disc angle from baseline was -1.1° in the arthroplasty group compared with -2.3° in the fusion group[3](#_ENREF_3). Anakwenze et al found that there was a greater loss of lordosis in patients treated with C-TDR compared with ACDF between baseline and 24 months (-1.4 ± 2.9° versus -1.8 ± 2.4°), a difference that was nearly statistically significant (*P* = .05). Both treatments resulted in statistically significant within-group losses in lordosis at the inferior level (*P* = .001 for both)[1](#_ENREF_1).

**Cervical sagittal alignment/lordosis *(Supplemental Table 6)***

Two RCTs[1](#_ENREF_1),[5](#_ENREF_5) and two retrospective[9](#_ENREF_9),[10](#_ENREF_10) cohort studies reported on the sagittal alignment of the entire cervical spine, which was measured between C2 and C7 in all but one study[1](#_ENREF_1). Anakwenze et al found that the change in cervical alignment from baseline to 24 months was not significantly different between the arthroplasty and fusion groups (3.9 ± 8.4° versus 3.1 ± 8.1°, respectively) (*P* = .49). Overall, the cervical spine became significantly more lordotic in both treatment groups (*P* ≤ .001)[1](#_ENREF_1). Sasso et al found that overall sagittal alignment was similar in both the C-TDR and fusion groups preoperatively (0.7 ± 11.7° versus 0.5 ± 10.9°, respectively) and at 24 months (4.4 ± 12.8° versus 5.8 ± 9.4°, respectively; *P* = .71). The change in global cervical alignment was similar between groups (3.7° versus 5.3°, respectively). In this study, cervical lordosis did not change significantly within either treatment group (*P* ≥ .12)[5](#_ENREF_5). Together, data from two RCTs suggest that the change in global cervical sagittal alignment from baseline to 24 months is similar between treatment groups (SMD, -0.03° (95% CI, -0.29°, 0.23°)(*I*2= 0%)).

Ahn et al reported that the cervical spine became more lordotic in both the arthroplasty and ACDF groups at a mean follow-up of 25 months (11.5 ± 8.9° versus 14.2 ± 8.8°, respectively) (baseline values: 6.6 ± 8.1° versus 10.7 ± 9.6°, respectively). However, the change in lordosis from baseline appeared similar between treatment groups (4.9° versus 3.5°, respectively; p-value not reported). The within-group change in disc angle was significant in the C-TDR (*P* < .05) but not the ACDF group (*P* ≥ .05)[9](#_ENREF_9). Park et al (2008) found that, compared with preoperative values (29.8° versus 24.3°, respectively), cervical lordosis decreased in both treatment groups by 6 months (28.6° versus 17.7°). The authors did not report whether the difference between treatment groups was statistically significant, however the change in lordosis was greater in the fusion group (-1.2° versus -6.6°, respectively)[10](#_ENREF_10).

**Supplemental Table. Adjacent segment range of motion**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study design** | **Time point (mos.)** | **Treatment** | **n (preop)** | **n (postop)** | **Cranial AS ROM (°)** | **Caudal AS ROM (°)** |
| **Preop** | **Postop** | **Preop** | **Postop** |
| Park 2011[3](#_ENREF_3) | RCT | 12  | TDR | 272 | NR | 9.8 ± 5.2 | 10.8 ± 5.5 | 7.3 ± 4.4 | 8.0 ± 5.3 |
| ACDF | 182 | NR | 9.6 ± 5.1 | 11.0 ± 5.5 | 7.8 ± 5.2 | 8.7 ± 5.3 |
| Nabhan[6](#_ENREF_6" \o "Nabhan, 2011 #11)  | RCT | 12 | TDR | 10 | 10 | NR | 14.5 | NR | NR |
| ACDF | 10 | 10 | NR | 18.1 | NR | NR |
| Powell[4](#_ENREF_4) | RCT | 12 | TDR | 22 | NR | 8.5 | 12.4 | 6.4 | 13.9 |
| ACDF | 26 | NR | 9.6 | 13.2 | 8.4 | 11.4 |
| Auerbach[2](#_ENREF_2" \o "Auerbach, 2011 #10) | RCT | 24 | TDR | 103 | 93 | 24.1 ± 7.7 | 23.1 ± 5.3 | 18.1 ± 8.4 | 18.7 ± 8.4 |
| ACDF | 106 | 91 | 23.6 ± 7.9 | 26.9 ± 9.7 | 18.8 ± 9.8 | 24.7 ± 9.5 |
| Park 2008[10](#_ENREF_10) | Cohort | 6-12 | TDR | 21 | NR | 14.4 | 12.6 | 11.3 | 11.6 |
| ACDF | 32 | NR | 10.6 | 11.7 | 10.2 | 11.3 |
| Rabin[11](#_ENREF_11) | Cohort | 24 | TDR | 10 | NR | 10.8 | 12.6 | 11.3 | 11.6 |
| ACDF | 10 | NR | 10.6 | 11.7 | 10.2 | 11.3 |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | Cohort | mean 25 | TDR | 18 | NR | 9.7 ± 5.5 | 11.2 ± 3.5 | 9.1 ± 4.5 | 9.7 ± 4.3 |
| ACDF | 20 | NR | 9.7 ± 4.5 | 12.9 ± 3.9 | 8.1 ± 3.4 | 10.3 ± 4.1 |
| Kim (1-level)[8](#_ENREF_8) | Cohort | mean 18 | TDR | 39 | NR | 8.7 ± 2.1 | 9.5 ± 2.1  | 8.3 ± 2.3 | 9.2 ± 2.4 |
| ACDF | 26 | NR | 9.4 ± 1.3 | 10.2 ± 1.4 | 11.4 ± 2.3 | 10.8 ± 3.4 |
| Kim (2-level)[8](#_ENREF_8) | Cohort | mean 20 | TDR | 12 | NR | 9.0 ± 1.6 | 9.9 ± 1.8 | 8.5 ± 1.9 | 9.4 ± 2.1 |
| ACDF | 28 | NR | 7.7 ± 1.1 | 4.3 ± 0.9 | 5.5 ± 1.7 | 6.2 ± 1.5 |
| **Adjacent segment not specified**  |  | **Preop AS ROM (°)** | **Postop AS ROM (°)** |
| Peng-Fei[7](#_ENREF_7" \o "Peng-Fei, 2008 #13)  | RCT | 12 | TDR | N = 24 | 24 | 12.8 ± 5.7 | 11.2 ± 3.9 |
| ACDF | 11.9 ± 5.8 | 11.4 ± 4.9 |
| Yi[12](#_ENREF_12) | Cohort | 23 TDR14 Fusion | TDR | 15 | NR | 13.8 ± 3.9 | 14.1 ± 3.4 |
| ACDF | 13 | NR | 10.4 ± 6.4 | 12.1 ± 4.5 |

NR: not reported

\* *P* < .05 (between-group differences)

**Supplemental Table. Global cervical range of motion**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study design** | **Time point (mos.)** | **Treatment** | **n (preop)** | **n (postop)** | **Global ROM (°)** |
| **Preop** | **Postop** |
| Auerbach[2](#_ENREF_2" \o "Auerbach, 2011 #10) | RCT | 24 | TDR | 103 | 93 | 46.0 ± 14.8 | 51.9 ± 13.8 |
| ACDF | 106 | 91 | 43.4 ± 14.5 | 42.6 ± 13.7 |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | Cohort | mean 25 | TDR | 18 | NR | 47.5 ± 16.5 | 52.1 ± 12.2 |
| ACDF | 20 | NR | 42.3 ± 12.3 | 42.5 ± 9.8 |
| Yi[12](#_ENREF_12) | Cohort | 23 TDR14 Fusion | TDR | 15 | NR | 56.5 ± 16.1 | 57.0 ± 17.2 |
| ACDF | 13 | NR | 42.0 ± 19.8 | 42.3 ± 8.8 |

NR: not reported

\* *P* < .05 (between-group differences)

**Supplemental Table. Adjacent segment center of rotation**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study design** | **Time point (mos.)** | **Treatment** | **n (preop)** | **n (postop)** | **Cranial AS COR-X (mm)** | **Caudal AS COR-X (mm)** |
| **Preop** | **Postop** | **Preop** | **Postop** |
| Park 2011[3](#_ENREF_3) | RCT | 12  | TDR | 272 | NR | -0.8 ± 0.9 | -0.9 ± 0.8 | -0.8 ± 0.9 | -0.8 ± 1.0 |
| ACDF | 182 | NR | 0.6 ± 0.8 | -0.8 ± 0.9 | -0.6 ± 1.0 | -0.5 ± 1.0 |
| Powell[4](#_ENREF_4) | RCT | 24 | TDR | 22 | NR | -1.4 | -1.0\* | -2.6 | -2.1 |
| ACDF | 26 | NR | -2.4 | -2.6\* | -2.8 | -3.2 |
|  | **Caudal AS COR-X (mm)** | **Caudal AS COR-X (mm)** |
| **Preop** | **Postop** | **Preop** | **Postop** |
| Park 2011[3](#_ENREF_3) | RCT | 12  | TDR | 272 | NR | 4.0 ± 1.9 | 4.2 ± 1.8 | 1.6 ± 2.0 | 2.0 ± 1.9 |
| ACDF | 182 | NR | 4.0 ± 2.1 | 4.1 ± 2.4 | 1.7 ± 1.8 | 2.0 ± 1.8 |
| Powell[4](#_ENREF_4) | RCT | 24 | TDR | 22 | NR | -8.1 | -7.8 | -13.0 | -13.2 |
| ACDF | 26 | NR | -9.4 | -8.6 | -12.6 | -13.4 |

NR: not reported

\* *P* < .05 (between-group differences); though it did not appear that the authors controlled for baseline differences.

**Supplemental Table. Adjacent segment sagittal alignment**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study design** | **Time point (mos.)** | **Treatment** | **n (preop)** | **n (postop)** | **Cranial AS alignment (°)** | **Caudal AS alignment (°)** |
| **Preop** | **Postop** | **Preop** | **Postop** |
| Park 2011[3](#_ENREF_3) | RCT | 12  | TDR | 272 | NR | 2.8 ± 4.6 | 3.6 ± 4.7 | 4.3 ± 3.8 | 3.2 ± 4.1 |
| ACDF | 182 | NR | 3.3 ± 4.4 | 3.2 ± 4.9 | 5.0 ± 3.8 | 2.7 ± 4.2 |
| Anakwenze[1](#_ENREF_1" \o "Anakwenze, 2009 #9) | RCT | 24 | TDR | 89 | NR | 2.4 ± 4.4 | 3.4 ± 5.1 | 4.5 ± 3.9 | 3.1 ± 4.5\* |
| ACDF | 91 | NR | 1.7 ± 4.2 | 2.6 ± 4.5 | 3.2 ± 4.0 | 1.4 ± 3.5\* |

NR: not reported

\* *P* = .05 (between-group differences)

**Supplemental Table. Global cervical sagittal alignment**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Study design** | **Time point (mos.)** | **Treatment** | **n (preop)** | **n (postop)** | **Cervical alignment (°)** |
| **Preop** | **Postop** |
| Anakwenze[1](#_ENREF_1" \o "Anakwenze, 2009 #9) | RCT | 24 | TDR | 89 | NR | 5.0 ± 9.8 | 8.9 ± 10.6 |
| ACDF | 91 | NR | 4.4 ± 10.2 | 7.5 ± 11.0 |
| Sasso[5](#_ENREF_5) | RCT | 24 | TDR | 22 | NR | 0.7 ± 11.7 | 4.4 ± 12.8 |
| ACDF | 26 | NR | 0.5 ± 10.9 | 5.8 ± 9.4 |
| Park 2008[10](#_ENREF_10) | Cohort | 6-12 | TDR | 21 | NR | 29.8 | 24.3 |
| ACDF | 32 | NR | 28.6 | 17.7 |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | Cohort | mean 25 | TDR | 18 | NR | 6.6 ± 8.1 | 11.5 ± 8.9 |
| ACDF | 20 | NR | 10.7 ± 9.6 | 14.2 ± 8.8 |

NR: not reported

**Supplemental Table. Data used to calculate standardized mean difference (SMD).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Length****follow-up****(months)** | **N****(baseline)** | **Change in kinematic outcome (from baseline)** |  |  |  |
| **Arthroplasty** | **ACDF** | **Mean SD\*** | **SMD**† | **95% CI** |
| **Cranial adjacent segment ROM** |  |  |  |  |  |  |  |
| **Cranial adjacent segment ROM** |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Park 2011[3](#_ENREF_3) | 12 | 454 | 1.0 | 1.4 | 5.5 | 0.1 |  |
| Powell[4](#_ENREF_4) | 12 | 209 | -1.0 | 3.3 | 7.5 | -0.5 |  |
| Auerbach[2](#_ENREF_2" \o "Auerbach, 2011 #10) | 24 | 48 | 3.9 | 3.6 | 6.5‡ | -0.05 |  |
| **Cohort studies** |  |  |  |  |  |  |  |
| Park 2008[10](#_ENREF_10) | 6-12 | 53 | -1.8 | 1.1 | 2.7‡ | 1.1 |  |
| Rabin[11](#_ENREF_11) | 24 | 20 | 4.0 | 1.2 | 2.7‡ | -1.0 |  |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | mean 25 | 38 | 1.5 | 3.2 | 3.7 | 0.5 |  |
| Kim (1-level)[8](#_ENREF_8) | mean 18 | 65 | 0.8 | 0.8 | 1.8 | 0.00 |  |
| **POOLED**  |  |  |  |  |  | 0.23 | -0.10, 0.56 |
| **Caudal adjacent segment ROM** |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Park 2011[3](#_ENREF_3) | 12 | 454 | 0.7 | 0.9 | 5.3 | 0.04 |  |
| Auerbach[2](#_ENREF_2" \o "Auerbach, 2011 #10) | 12 | 209 | 0.6 | 5.9 | 9.0 | 0.6 |  |
| Powell[4](#_ENREF_4) | 24 | 48 | 7.5 | 3.0 | 7.1‡ | -0.6 |  |
| **Cohort studies** |  |  |  |  |  |  |  |
| Park 2008[10](#_ENREF_10) | 6-12 | 53 | 0.3 | 1.1 | 3.6‡ | 0.2 |  |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | mean 25 | 38 | 0.6 | 2.2 | 4.2 | 0.4 |  |
| Kim (1-level)[8](#_ENREF_8) | mean 18 | 65 | 0.9 | -0.6 | 2.9 | -0.5 |  |
| **POOLED** |  |  |  |  |  | 0.22 | -0.32, 0.75 |
| **Global cervical ROM**  |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Auerbach[2](#_ENREF_2" \o "Auerbach, 2011 #10) | 24 | 209 | 5.9 | -0.8 | 13.8 | -0.5 |  |
| **Cohort studies** |  |  |  |  |  |  |  |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | Mean 25 | 38 | 4.6 | 0.2 | 11.0 | -0.40 |  |
| Yi[12](#_ENREF_12) | 23 (TDR)14 (ACDF) | 28 | 0.5 | 0.3 | 13.0 | -0.02 |  |
| **POOLED** |  |  |  |  |  | -0.39 | -0.63, -0.14 |
| **Cranial adjacent segment alignment** |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Park 2011[3](#_ENREF_3) | 12 | 454 | 0.8 | -0.1 | 4.8 | -0.2 |  |
| Anakwenze[1](#_ENREF_1" \o "Anakwenze, 2009 #9) | 24 | 180 | 1.0 | 0.9 | 4.8 | -0.02 |  |
| **POOLED** |  |  |  |  |  | -0.14 | -0.30, 0.02 |
| **Caudal adjacent segment alignment** |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Park 2011[3](#_ENREF_3) | 12 | 454 | -1.1 | -2.3 | 4.2 | -0.3 |  |
| Anakwenze[1](#_ENREF_1" \o "Anakwenze, 2009 #9) | 24 | 180 | -1.4 | -1.8 | 4.0 | -0.1 |  |
| **POOLED** |  |  |  |  |  | -0.23 | -0.40, -0.06 |
| **Global cervical alignment** |  |  |  |  |  |  |  |
| **RCTs** |  |  |  |  |  |  |  |
| Anakwenze[1](#_ENREF_1" \o "Anakwenze, 2009 #9) | 24 | 180 | 3.9 | 3.1 | 10.8 | -0.1 |  |
| Sasso[5](#_ENREF_5) | 24 | 48 | 3.7 | 5.3 | 11.1 | 0.1 |  |
| **Cohort studies** |  |  |  |  |  |  |  |
| Park 2008[10](#_ENREF_10) | 6-12 | 53 | -1.2 | -6.6 | 8.9**‡** | -0.6 |  |
| Ahn[9](#_ENREF_9" \o "Ahn, 2009 #17) | Mean 25 | 38 | 4.9 | 3.5 | 8.9 | -0.2 |  |
| **POOLED** |  |  |  |  |  | -0.15 | -0.42, 0.12 |

CI: confidence interval; SD: standard deviation; SMD: standardized mean difference

\* mean of the SDs reported for the arthroplasty and ACDF treatment groups at last follow-up

† SMD = (change in ACDF score from baseline minus change in C-TDR score from baseline) / SD

**‡** Standard deviations not reported by the study, and was imputed. The reported SD is equal to the mean SD as reported by the other studies for that outcome/study ty

**Level of Evidence Summary Table**

**Methodological quality of therapeutic studies**

|  |  |  |  |
| --- | --- | --- | --- |
| **Methodological principle** | **Anakwenze 2009** | **Auerbach 2011** | **Ahn 2009** |
| **Study Design** |  |  |  |
| Randomized controlled trial | √ | √ |  |
| * Random sequence generation\*
 | +/- | + |  |
| * Allocation concealment\*
 | - | + |  |
| * Intention to treat\*
 | - | + |  |
| Cohort study  |  |  | √ |
| Case-control study |  |  |  |
| Case series |  |  |  |
| **Other Methods Implementation** |  |  |  |
| Independent or blind assessment  | + | + | + |
| Co-interventions applied equally | - | - | + |
| Complete follow-up of > 80% | - | + | - |
| Adequate sample size | + | + | + |
| Controlling for possible confounding† | - | + | - |
| **Evidence class** | **II** | **II** | **III** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Methodological principle** | **Kim 2009** | **Nabhan 2011** | **Park 2008** |
| **Study Design** |  |  |  |
| Randomized controlled trial |  | √ |  |
| * Random sequence generation\*
 |  | +/- |  |
| * Allocation concealment\*
 |  | +/- |  |
| * Intention to treat\*
 |  | - |  |
| Cohort study  | √ |  | √ |
| Case-control study |  |  |  |
| Case series |  |  |  |
| **Other Methods Implementation** |  |  |  |
| Independent or blind assessment  | - | - | - |
| Co-interventions applied equally | - | - | - |
| Complete follow-up of > 80% | - | + | - |
| Adequate sample size | + | + | + |
| Controlling for possible confounding† | - | - | - |
| **Evidence class** | **III** | **II** | **III** |

Continued on next page

|  |  |  |  |
| --- | --- | --- | --- |
| **Methodological principle** | **Park 2011** | **Peng-Fei 2008** | **Rabin 2007** |
| **Study Design** |  |  |  |
| Randomized controlled trial | √ | √ |  |
| * Random sequence generation\*
 | +/- | +/- |  |
| * Allocation concealment\*
 | - | - |  |
| * Intention to treat\*
 | - | - |  |
| Cohort study  |  |  | √ |
| Case-control study |  |  |  |
| Case series |  |  |  |
| **Other Methods Implementation** |  |  |  |
| Independent or blind assessment  | + | - | - |
| Co-interventions applied equally | - | + | - |
| Complete follow-up of > 80% | - | + | - |
| Adequate sample size | + | - | + |
| Controlling for possible confounding† | + | - | + |
| **Evidence class** | **II** | **II** | **III** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Methodological principle** | **Sasso****2011** | **Powell 2010** | **Yi 2009** |
| **Study Design** |  |  |  |
| Randomized controlled trial | √ | √ |  |
| * Random sequence generation\*
 | +/- | +/- |  |
| * Allocation concealment\*
 | - | - |  |
| * Intention to treat\*
 | - | - |  |
| Cohort study  |  |  | √ |
| Case-control study |  |  |  |
| Case series |  |  |  |
| **Other Methods Implementation** |  |  |  |
| Independent or blind assessment  | - | + | - |
| Co-interventions applied equally | - | - | - |
| Complete follow-up of > 80% | - | + | - |
| Adequate sample size | - | + | - |
| Controlling for possible confounding† | - | + | - |
| **Evidence class** | **II** | **II** | **III** |

“+” indicates study meets criteria, “-“ indicates study does not meet criteria or cannot be determined if study met criteria, “+/-“ indicates partial credit.

\* Applies to randomized controlled trials only.

† Authors must provide a description of robust baseline characteristics and control for those that are unequally distributed between treatment groups.

**Studies excluded after full-text review:**

|  | **Study** | **Reason for exclusion** |
| --- | --- | --- |
|  | **Burkus 2010**[**13**](#_ENREF_13) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Cheng 2011**[**14**](#_ENREF_14) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Cheng 2009**[**15**](#_ENREF_15) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Coric, Finger 2006**[**16**](#_ENREF_16) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Coric, Cassis 2010**[**5**](#_ENREF_5) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Coric, Nunley 2011**[**17**](#_ENREF_17) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Heller Sasso 2009**[**18**](#_ENREF_18) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Jawahar 2010 (3 FDA IDE trials)**[**19**](#_ENREF_19) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Kelly 2011**[**20**](#_ENREF_20) | Patient population and outcomes overlap with those reported by Auerbach et al (2011) |
|  | **Mummaneni 2007**[**21**](#_ENREF_21) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Murrey 2009**[**22**](#_ENREF_22) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Nabhan, Ahlhelm, Shariat 2007**[**23**](#_ENREF_23) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Nabhan, Ahlhelm, Pitzen 2007**[**24**](#_ENREF_24) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Nabhan, Steudel 2007**[**25**](#_ENREF_25) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Porcett 2004**[**26**](#_ENREF_26) | No actual data reported for kinematics. |
|  | **Sasso, Best 2008**[**27**](#_ENREF_27) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Sasso Best Metcalf 2008**[**28**](#_ENREF_28) | Follow-up kinematics data not reported for ACDF group. |
|  | **Sasso Anderson 2011**[**29**](#_ENREF_29) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Sasso Smucker 2007**[**30**](#_ENREF_30) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Shin 2009**[**31**](#_ENREF_31) | Intervention group included both arthroplasty and ACDF (one at each of two levels) |
|  | **Upadhyaya 2012**[**32**](#_ENREF_32) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Wigfield 2002**[**33**](#_ENREF_33) | Fusion approach not specified (ie., anterior and/or posterior). |
|  | **Zhang 2011**[**34**](#_ENREF_34) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Barrey 2012**[**35**](#_ENREF_35) | No ACDF control group |
|  | **Garrido Wilhite 2011**[**36**](#_ENREF_36)(post-hoc analysis of prospective study) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Huppert 2011**[**37**](#_ENREF_37) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Koakutsu 2010**[**38**](#_ENREF_38) | No C-TDR group |
|  | **Maldonado 2011**[**39**](#_ENREF_39) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Robertson 2005**[**40**](#_ENREF_40) | Kinematics of adjacent segments or entire cervical spine not evaluated. |
|  | **Watanabe 2011**[**41**](#_ENREF_41) | No C-TDR group |
|  | **Cheng 2007**[**42**](#_ENREF_42) | No C-TDR group |
|  | **Kowalczyk 2011**[**43**](#_ENREF_43) | No ACDF control (really a case series with data stratified for 3 different C-TDR devices) |
|  | **Lazaro 2010**[**44**](#_ENREF_44) | No ACDF control (really a case series with data stratified for 3 different C-TDR devices) |
|  | **Ryu 2010**[**45**](#_ENREF_45) | No ACDF control (really a case series with data stratified for 3 different C-TDR devices) |

1. Anakwenze OA, Auerbach JD, Milby AH, Lonner BS, Balderston RA. Sagittal cervical alignment after cervical disc arthroplasty and anterior cervical discectomy and fusion: results of a prospective, randomized, controlled trial. Spine 2009;34:2001-7.

2. Auerbach JD, Anakwenze OA, Milby AH, Lonner BS, Balderston RA. Segmental contribution toward total cervical range of motion: a comparison of cervical disc arthroplasty and fusion. Spine 2011;36:E1593-9.

3. Park DK, Lin EL, Phillips FM. Index and adjacent level kinematics after cervical disc replacement and anterior fusion: in vivo quantitative radiographic analysis. Spine 2011;36:721-30.

4. Powell JW, Sasso RC, Metcalf NH, Anderson PA, Hipp JA. Quality of spinal motion with cervical disk arthroplasty: computer-aided radiographic analysis. Journal of spinal disorders & techniques 2010;23:89-95.

5. Sasso RC, Metcalf NH, Hipp JA, Wharton ND, Anderson PA. Sagittal alignment after Bryan cervical arthroplasty. Spine 2011;36:991-6.

6. Nabhan A, Ishak B, Steudel WI, Ramadhan S, Steimer O. Assessment of adjacent-segment mobility after cervical disc replacement versus fusion: RCT with 1 year's results. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2011;20:934-41.

7. Peng-Fei S, Yu-Hua J. Cervical disc prosthesis replacement and interbody fusion: a comparative study. International orthopaedics 2008;32:103-6.

8. Kim SW, Limson MA, Kim SB, et al. Comparison of radiographic changes after ACDF versus Bryan disc arthroplasty in single and bi-level cases. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2009;18:218-31.

9. Ahn PG, Kim KN, Moon SW, Kim KS. Changes in cervical range of motion and sagittal alignment in early and late phases after total disc replacement: radiographic follow-up exceeding 2 years. Journal of neurosurgery Spine 2009;11:688-95.

10. Park JH, Roh KH, Cho JY, Ra YS, Rhim SC, Noh SW. Comparative analysis of cervical arthroplasty using mobi-c(r) and anterior cervical discectomy and fusion using the solis(r) -cage. Journal of Korean Neurosurgical Society 2008;44:217-21.

11. Rabin D, Pickett GE, Bisnaire L, Duggal N. The kinematics of anterior cervical discectomy and fusion versus artificial cervical disc: a pilot study. Neurosurgery 2007;61:100-4; discussion 4-5.

12. Yi S, Lim JH, Choi KS, et al. Comparison of anterior cervical foraminotomy vs arthroplasty for unilateral cervical radiculopathy. Surgical neurology 2009;71:677-80, discussion 80.

13. Burkus JK, Haid RW, Traynelis VC, Mummaneni PV. Long-term clinical and radiographic outcomes of cervical disc replacement with the Prestige disc: results from a prospective randomized controlled clinical trial. Journal of neurosurgery Spine 2010;13:308-18.

14. Cheng L, Nie L, Li M, Huo Y, Pan X. Superiority of the Bryan((R)) disc prosthesis for cervical myelopathy: a randomized study with 3-year followup. Clinical orthopaedics and related research 2011;469:3408-14.

15. Cheng L, Nie L, Zhang L, Hou Y. Fusion versus Bryan Cervical Disc in two-level cervical disc disease: a prospective, randomised study. Int Orthop 2009;33:1347-51.

16. Coric D, Finger F, Boltes P. Prospective randomized controlled study of the Bryan Cervical Disc: early clinical results from a single investigational site. Journal of neurosurgery Spine 2006;4:31-5.

17. Coric D, Nunley PD, Guyer RD, et al. Prospective, randomized, multicenter study of cervical arthroplasty: 269 patients from the Kineflex|C artificial disc investigational device exemption study with a minimum 2-year follow-up: clinical article. Journal of neurosurgery Spine 2011;15:348-58.

18. Heller JG, Sasso RC, Papadopoulos SM, et al. Comparison of BRYAN cervical disc arthroplasty with anterior cervical decompression and fusion: clinical and radiographic results of a randomized, controlled, clinical trial. Spine (Phila Pa 1976) 2009;34:101-7.

19. Jawahar A, Cavanaugh DA, Kerr EJ, 3rd, Birdsong EM, Nunley PD. Total disc arthroplasty does not affect the incidence of adjacent segment degeneration in cervical spine: results of 93 patients in three prospective randomized clinical trials. The spine journal : official journal of the North American Spine Society 2010;10:1043-8.

20. Kelly MP, Mok JM, Frisch RF, Tay BK. Adjacent segment motion after anterior cervical discectomy and fusion versus Prodisc-c cervical total disk arthroplasty: analysis from a randomized, controlled trial. Spine 2011;36:1171-9.

21. Mummaneni PV, Burkus JK, Haid RW, Traynelis VC, Zdeblick TA. Clinical and radiographic analysis of cervical disc arthroplasty compared with allograft fusion: a randomized controlled clinical trial. Journal of neurosurgery Spine 2007;6:198-209.

22. Murrey D, Janssen M, Delamarter R, et al. Results of the prospective, randomized, controlled multicenter Food and Drug Administration investigational device exemption study of the ProDisc-C total disc replacement versus anterior discectomy and fusion for the treatment of 1-level symptomatic cervical disc disease. The spine journal : official journal of the North American Spine Society 2009;9:275-86.

23. Nabhan A, Ahlhelm F, Shariat K, et al. The ProDisc-C prosthesis: clinical and radiological experience 1 year after surgery. Spine 2007;32:1935-41.

24. Nabhan A, Ahlhelm F, Pitzen T, et al. Disc replacement using Pro-Disc C versus fusion: a prospective randomised and controlled radiographic and clinical study. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2007;16:423-30.

25. Nabhan A, Steudel WI, Pape D, Ishak B. Segmental kinematics and adjacent level degeneration following disc replacement versus fusion: RCT with three years of follow-up. J Long Term Eff Med Implants 2007;17:229-36.

26. Porchet F, Metcalf NH. Clinical outcomes with the Prestige II cervical disc: preliminary results from a prospective randomized clinical trial. Neurosurgical focus 2004;17:E6.

27. Sasso RC, Best NM. Cervical kinematics after fusion and bryan disc arthroplasty. Journal of spinal disorders & techniques 2008;21:19-22.

28. Sasso RC, Best NM, Metcalf NH, Anderson PA. Motion analysis of bryan cervical disc arthroplasty versus anterior discectomy and fusion: results from a prospective, randomized, multicenter, clinical trial. Journal of spinal disorders & techniques 2008;21:393-9.

29. Sasso RC, Anderson PA, Riew KD, Heller JG. Results of cervical arthroplasty compared with anterior discectomy and fusion: four-year clinical outcomes in a prospective, randomized controlled trial. J Bone Joint Surg Am 2011;93:1684-92.

30. Sasso RC, Smucker JD, Hacker RJ, Heller JG. Artificial disc versus fusion: a prospective, randomized study with 2-year follow-up on 99 patients. Spine (Phila Pa 1976) 2007;32:2933-40; discussion 41-2.

31. Shin DA, Yi S, Yoon do H, Kim KN, Shin HC. Artificial disc replacement combined with fusion versus two-level fusion in cervical two-level disc disease. Spine 2009;34:1153-9; discussion 60-1.

32. Upadhyaya CD, Wu JC, Trost G, et al. Analysis of the three United States Food and Drug Administration investigational device exemption cervical arthroplasty trials. Journal of neurosurgery Spine 2012;16:216-28.

33. Wigfield C, Gill S, Nelson R, Langdon I, Metcalf N, Robertson J. Influence of an artificial cervical joint compared with fusion on adjacent-level motion in the treatment of degenerative cervical disc disease. Journal of neurosurgery 2002;96:17-21.

34. Zhang X, Zhang X, Chen C, et al. Randomized, Controlled, Multicenter, Clinical Trial Comparing BRYAN Cervical Disc Arthroplasty with Anterior Cervical Decompression and Fusion in China. Spine 2011.

35. Barrey C, Champain S, Campana S, Ramadan A, Perrin G, Skalli W. Sagittal alignment and kinematics at instrumented and adjacent levels after total disc replacement in the cervical spine. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2012.

36. Garrido BJ, Wilhite J, Nakano M, et al. Adjacent-level cervical ossification after Bryan cervical disc arthroplasty compared with anterior cervical discectomy and fusion. The Journal of bone and joint surgery American volume 2011;93:1185-9.

37. Huppert J, Beaurain J, Steib JP, et al. Comparison between single- and multi-level patients: clinical and radiological outcomes 2 years after cervical disc replacement. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2011;20:1417-26.

38. Koakutsu T, Morozumi N, Ishii Y, et al. Anterior decompression and fusion versus laminoplasty for cervical myelopathy caused by soft disc herniation: a prospective multicenter study. Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association 2010;15:71-8.

39. Maldonado CV, Paz RD, Martin CB. Adjacent-level degeneration after cervical disc arthroplasty versus fusion. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2011;20 Suppl 3:403-7.

40. Robertson JT, Papadopoulos SM, Traynelis VC. Assessment of adjacent-segment disease in patients treated with cervical fusion or arthroplasty: a prospective 2-year study. Journal of neurosurgery Spine 2005;3:417-23.

41. Watanabe S, Inoue N, Yamaguchi T, et al. Three-dimensional kinematic analysis of the cervical spine after anterior cervical decompression and fusion at an adjacent level: a preliminary report. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2011.

42. Cheng JS, Liu F, Komistek RD, Mahfouz MR, Sharma A, Glaser D. Comparison of cervical spine kinematics using a fluoroscopic model for adjacent segment degeneration. Invited submission from the Joint Section on Disorders of the Spine and Peripheral Nerves, March 2007. Journal of neurosurgery Spine 2007;7:509-13.

43. Kowalczyk I, Lazaro BC, Fink M, Rabin D, Duggal N. Analysis of in vivo kinematics of 3 different cervical devices: Bryan disc, ProDisc-C, and Prestige LP disc. Journal of neurosurgery Spine 2011;15:630-5.

44. Lazaro BC, Yucesoy K, Yuksel KZ, et al. Effect of arthroplasty design on cervical spine kinematics: analysis of the Bryan Disc, ProDisc-C, and Synergy disc. Neurosurgical focus 2010;28:E6.

45. Ryu KS, Park CK, Jun SC, Huh HY. Radiological changes of the operated and adjacent segments following cervical arthroplasty after a minimum 24-month follow-up: comparison between the Bryan and Prodisc-C devices. Journal of neurosurgery Spine 2010;13:299-307.